



# Government Mandatory Inspection Point (GMIP)



Independent Assessment  
Final Report  
January 22, 2004

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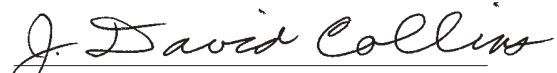
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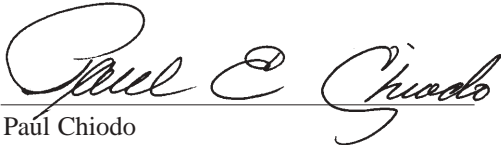
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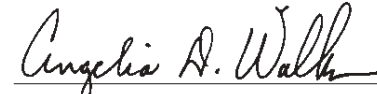
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# Executive Summary

The Government Mandatory Inspection Point Independent Assessment Team was chartered to assess Government Mandatory Inspection Points for two of the five Space Shuttle Program elements, the Orbiter and External Tank. The Independent Assessment Team was to perform the assessment on the Quality Planning and Requirements Document, the Mandatory Inspection Document, the Government Mandatory Inspection Point processes and criteria, and the organizations that perform them.

The Quality Planning Requirements Document establishes the general requirements for the application of Orbiter processing Government Mandatory Inspection Points. Orbiter processing is performed at Kennedy Space Center and is the responsibility of the Kennedy Space Center Shuttle Processing Directorate. The Mandatory Inspection Document is a requirements document listing all Government Mandatory Inspection Points to be performed during External Tank assembly. External Tank assembly is performed at the Michoud Assembly Facility and is the responsibility of the Marshall Space Flight Center.

The Independent Assessment Team visited both the Kennedy Space Center and the Michoud Assembly Facility. The Team reviewed and assessed the facilities, the documentation, and the processes, and held discussions with all levels of responsible Government personnel. The Independent Assessment Team assessed the NASA Quality Assurance Programs for these Space Shuttle Program elements, with a focus on Government Mandatory Inspection Points, as it was impossible to properly assess the effectiveness of the Government Mandatory Inspection Points without understanding the context in which they were applied.

The Independent Assessment Team has found the NASA Quality Assurance Programs, in place for these Space Shuttle Program elements today, are relatively good based upon the ground rules that were in effect when they were formulated.

- The NASA job was transitioning to surveillance of contractor activity (insight) as part of a move to performance-based contracting and toward privatization.
  - The contractor would be almost solely responsible for the quality of the vehicle.
- NASA Space Shuttle Program Government Mandatory Inspection Points were to be phased to zero and replaced with surveillance and audits.
- The overall civil service workforce would be reduced, and, as the Government Mandatory Inspection Points were phased to zero, the Quality Assurance Specialist workforce would be reduced significantly.

It should be noted the program elements and their Centers' Safety and Mission Assurance representatives successfully fought to retain Government Mandatory Inspection Points and a level of Government quality assurance.

However, the ground rules have changed, and NASA should reassess their quality assurance requirements based on the new premise base and establish a NASA quality assurance effort that fulfills those requirements. The workforce should be adjusted and trained accordingly.

The new premise base is as follows.

- The Space Shuttle is a developmental vehicle that is also an aging vehicle.
- The Space Shuttle must function for at least another decade.
- The Space Shuttle Program is a relatively high-risk program.
- The NASA Safety and Mission Assurance Quality Assurance Program must help to ensure both safe hardware and an effective contractor quality program.



*Figure 1.*

The Government Mandatory Inspection Point Independent Assessment Team dedicates their work and this report to the crew of STS-107. L–R: Mission Specialist Kalpana Chawla, Payload Commander Michael Anderson, Pilot William “Willie” McCool, Commander Rick Husband, Mission Specialists Laurel Clark and David Brown, and Payload Specialist Ilan Ramon.

# Foreword and Acknowledgments

The Government Mandatory Inspection Point (GMIP) Independent Assessment was performed at the Shuttle processing facilities, Kennedy Space Center, and the External Tank assembly facilities at the Marshall Space Flight Center Michoud Assembly Facility. The representatives of the Space Shuttle Program (SSP) at each of these facilities provided the utmost cooperation and access, and thus enabled the team to perform a thorough assessment.

During the GMIP Independent Assessment, Shuttle processing assessment information was freely exchanged and discussions were open. Mr. Mike Wetmore set the stage at Kennedy Space Center with his opening brief to the Independent Assessment Team, and the Team solicited discussion opportunities from all interested parties. Discussions were held with Shuttle Safety and Mission Assurance management at the Division and Branch levels, Quality Assurance Specialists (QAS's), quality engineers, process analysts, and systems engineering personnel. Discussions included the Space Flight Operations Contract Safety and Mission Assurance manager and individuals originally involved in the Kennedy Space Center GMIP reduction process. Discussions at the Marshall Space Flight Center Michoud Assembly Facility were conducted in similar fashion with the initial briefing provided by Mr. Alex Adams, Marshall Space Flight Center Shuttle Safety and Mission Assurance manager. This initial briefing was augmented by an onsite briefing provided by Mr. Mike Smiles, Michoud Assembly Facility Return to Flight, and Mr. Chris Reinecke, Michoud Safety and Mission Assurance senior resident representative. They were involved in the GMIP reduction process at the Michoud Assembly Facility and provided an excellent history of the activity to date. Discussions at Michoud Assembly Facility included quality engineering and QAS personnel, as well as Lockheed Martin Safety and Mission Assurance management.

The Chair and Co-Chair of the Independent Assessment Team would like to extend our sincere thanks to all who served or participated in this endeavor. This was an extensive effort, requiring more than three months of effort from each Team member.

There was one consulting contract required for the effort of Mr. Gardner, funded by Code Q. The other costs were travel expenses for multiple trips to Kennedy Space Center, Michoud Assembly Facility, and NASA Headquarters during the assessment. These expenses were provided via invitational travel orders from the Kennedy Space Center Safety, Health, and Independent Assessment. Development costs for the final presentation and report were borne by the Kennedy Space Center Safety, Health, and Independent Assessment, and the Office of the Chief Engineer—so our thanks to them as well.

The GMIP Independent Assessment Team also would like to give credit for information regarding the Government Mandatory Inspection Point reduction and changes to the Shuttle quality program gained through review of a number of past GMIP and quality program reviews of the Shuttle program. They include the Aerospace Safety Advisory Panel reports, Safety and Mission Assurance reviews, and Space Shuttle independent assessments.

Finally, a special thanks to Maxine Cherry for our travel arrangements, Michelle Collins for report and presentation review, formatting, and rewriting, and lastly to our coworkers and families who bore the brunt of the extra work placed upon them so that we could perform this important task.

# 1. Introduction

After the loss of the Space Shuttle Columbia, the NASA Administrator activated the standing International Space Station and Space Shuttle Mishap Interagency Investigation Board. Shortly thereafter, the Administrator formally chartered this Board as the Columbia Accident Investigation Board (CAIB) and committed the Agency to 1) finding the cause of the accident, 2) fixing it, and 3) returning the Shuttle safely to flight. To achieve the first objective, the Administrator asked the Board to determine the facts independently, as well as the actual or probable causes of the accident, and to recommend to NASA preventative or other appropriate actions to preclude recurrence of a similar nature. The Board provided a thorough study of the accident and prepared the recommendations NASA would use as a roadmap to return to flight.

To ensure the implementation of the CAIB's recommendations, the Administrator selected the leads for the Return to Flight (RTF) Task Group that would develop an independent assessment of NASA's strategy for returning to flight. Additionally, the Administrator selected the Associate Deputy Administrator for Technical Programs and the Associate Administrator for Space Flight to be co-chairs for the newly chartered Space Flight Leadership Council. This Council was to address issues beyond the CAIB Report's recommendations, as well as respond to internal NASA reviews and observations from external sources.

The Space Flight Leadership Council consists of the co-chairs, the Associate Administrator for Safety and Mission Assurance (S&MA), the Deputy Associate Administrator for the Space Shuttle, and the four Code M Center Directors. The Council wrote NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond, a living document that contains reviews and assessments of each course of action recommended by the RTF Task Group. This document provides direction to the Space Shuttle Program (SSP) for implementation and will be modified as progress is accomplished or as other safety concerns require.

To address issues contained in the Administrator's second and third objectives, the co-chairs of the Space Flight Leadership Council chartered an Independent Assessment Team (IAT) to assess the Quality Planning Requirements Document (QPRD); the Mandatory Inspection Document (MID); the GMIP processes and criteria for two of the five Space Shuttle elements, Orbiter and External Tank; and the organizations that perform them. The membership of this team was concurred upon by the S&MA Directors at Kennedy Space Center (KSC), Johnson Space Center (JSC), and Marshall Space Flight Center (MSFC). The above action is addressed within NASA's Implementation Plan for Return to Flight and Beyond as SSP-1.

The IAT, prior to performing the assessment, developed a document entitled Terms of Reference (TOR) for the Independent Assessment Team of the Space Shuttle Program Government Mandatory Inspection Points (KMJ-3017). This document provided the charter for the team and outlined the scope and deliverables.

## 1.1 Purpose

The purpose of this report is to respond to the Space Flight Leadership Council's report entitled NASA's Implementation Plan for Return to Flight and Beyond, action SSP-1, which states:

NASA will commission an assessment, independent of the Space Shuttle Program, of the Quality Planning and Requirements Document (QPRD) to determine the effectiveness of GMIP criteria in assuring verification of critical functions before each Shuttle mission. The assessment should sample the existing GMIP's against the QPRD criteria and determine the adequacy of the GMIP's in meeting the criteria. Over the long term, NASA should periodically review the effectiveness of the QPRD inspection criteria against ground processing and flight experience to determine if GMIP's are effective in assuring safe flight operations.

Additionally, this report responds to some recommendations in the Columbia Accident Investigation Board Report, Volume II, Appendix D.a.



## 1.2 Scope

The IAT evaluated the effectiveness of the SSP's GMIP's verification process for the Shuttle Processing Directorate at KSC and the ET Project at the Michoud Assembly Facility (MAF). The group emphasized policy review and hardware process evaluation associated with selected existing GMIP's. The results of these assessments, as well as the potential effect on return to flight, will be provided to the Co-Chairs of the Space Flight Leadership Council as well as the Associate Administrator of NASA's Office of Safety and Mission Assurance (OSMA). The document will then be provided to the RTF Planning Team for disposition.

The IAT assessed the QPRD for KSC and the MID for the MAF to determine the effectiveness of GMIP criteria in assuring verification of critical functions before each Shuttle mission. The IAT sampled existing GMIP's against the QPRD and MID criteria and determined the adequacy of the sampled GMIP's in meeting the criteria. The IAT also performed assessments to understand GMIP philosophy and history, and to assess GMIP policies, processes, and activities, workforce adequacy, previous assessments, and other pertinent GMIP data. The IAT requested and received presentations, data, and formal inputs, workforce discussions, information, and support from the program and S&MA organizations.

The IAT performed analyses and reviews of all the aforementioned data and all forms of information that were provided and witnessed. While the focus of the IAT was on the GMIP process, this assessment includes, to a lesser depth, a review of the overall quality program. It is not possible to evaluate the application of GMIP's without also reviewing the other major proponents of a good quality system—surveillance that includes process validation and monitoring, trend analysis, and quality system assessment (audits). All quality program elements must work together to ensure an effective contractor quality program and thus a robust product. The IAT developed this report, including the recommendations, based on the observations and findings of the assessment.

## 2. Government Mandatory Inspection Point Background, History, and Context

### 2.1 GMIP—Where Does It Come From?

The general definition of GMIP's and their applicability are broadly defined in the Federal Acquisition Regulations (FAR) and in NASA Agency policy. Each Center and program has the latitude to interpret GMIP's in the way which best allows them to ensure quality and safety within the constraints of the program. There is no Agency standard for what a GMIP should achieve. The way a GMIP is defined at the detail level differs from Center to Center, program to program, and often even within the program. There was a draft standard written in 1997, NASA Assurance Standard for Government Mandatory Inspection Points (GMIP), Process for Establishment, Management, and Control of Mandatory Inspection Points. This document was distributed for initial review but did not survive the review process and was not released.

The FAR and NASA Procedures and Guidelines (NPG) 8735.2 (Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts) stipulate that inspections (GMIP's) are only one part of an overall comprehensive Government contract QA Program. Other elements of Government oversight of contractor performance include process/system audits and trending to identify weaknesses in contractor performance and guide the Government verification process. The risk of not having a comprehensive Government contract QA Program is that the Government cannot adjust (increase/decrease/change type and location) the level of inspections, because it does not have an adequate understanding of the contractor's quality performance. Thus, GMIP's must be examined in the context of the overall adequacy of the Government evaluation of contractor quality.

### 2.2 GMIP Reductions and Premise Base

GMIP's went through two major reductions and some evolutionary reduction during the post-Challenger era. Based on discussions during this assessment, both the KSC and MAF GMIP reduction efforts appeared to have the same fundamental underlying set of premises that established the QA Program ground rules.

- The NASA job was transitioning to surveillance of contractor activity (insight) as part of a move toward privatization.
- The contractor would be almost solely responsible for the quality of the vehicle.
- NASA SSP GMIP's were to be reduced, phased to zero, and replaced with surveillance and process audits.
- The overall civil service workforce would be reduced, and, as the GMIP's were phased to zero, the QAS workforce would be reduced significantly.

These premises were due to the paradigm shift created by the NASA Zero-Base Review (ZBR), transition of previous governmental functions to a contractor, and the downsizing of the NASA civil service workforce. A serious and diligent effort was made to ensure that no matter what type of quality program was put in place, NASA would be able to assure the Space Shuttle was safe to fly. The KSC Shuttle Processing and Safety, Reliability, and Quality Assurance (SR&QA) Directorates objected to the elimination of all GMIP's, as did MSFC S&MA. In the final outcome, not all Government inspectors were eliminated, nor were all GMIP's eliminated. As a result of their efforts to retain some GMIP's, they were allowed to develop the KSC "litmus test" and the MAF criteria to guide GMIP retention. NASA leadership from both program elements and S&MA stated that flight safety (using Failure Mode and Effects Analysis (FMEA)/Critical Items Lists (CIL's), Hazard Analysis (HA's), SAA's, etc.) was the primary determinant for GMIP retention. The SSP and S&MA managers also attempted to put new quality systems into place or reinforce existing quality systems.

## 2.3 GMIP Processes Today

The KSC Ground Operations QPRD and the MSFC MID define significant portions of the requirements for the SSP's Orbiter and External Tank (ET) quality assurance verification program. The QPRD identifies assurance requirements for the Orbiter and some interfacing systems. These requirements translate into GMIP's. KSC uses witness and verify as the types of actions used to meet the assurance requirements contained within the QPRD. In contrast, the MSFC ET Project uses witness, verify, and inspect at the MAF. The determination of what assurances are required is a risk-based process. For NASA, Mandatory Inspection Point (MIP) determination is in accordance with NASA Procedure and Guideline (NPG) 8735.2, Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts. This NPG sets forth general information for surveillance of NASA contracts and established detailed requirements for the direction and management of Federal agencies and surveillance support contractors in performing Safety and Mission Assurance surveillance functions for NASA contracts. The MIP selection process may include, but is not limited to, the following considerations:

1. experience with contractor performance;
2. design, safety, drawing, engineering, configuration, specification, and technical document reviews;
3. reliability, maintainability, and systems safety tests and analyses;
4. Failure Mode and Effects Analysis (FMEA), CILs, and HA's;
5. contractor quality assurance manuals, requirements, and selected quality system documents (e.g., the quality plan or quality policy);
6. the delegated agency or the NASA S&MA lead may determine whether other actions or characteristics should be identified as mandatory actions or characteristics on a temporary basis;
7. input from the technical monitor; and
8. assessment of the best practices and benchmarking for inspection procedures and rationale used by other systems (aircraft, ships, nuclear plants, etc.).

The delegated agency or the NASA S&MA lead may determine other actions or characteristics that should be identified as mandatory actions or characteristics on a temporary basis. In addition, the program uses the Operational Hazard Analyses and critical Operations and Maintenance Requirements and Specifications Document (OMRSD) requirements to identify GMIP's.

## 2.4 GMIP History—Shuttle Processing

After Challenger, the NASA Office of Space Flight (Code M) Centers increased their S&MA and engineering organizations to meet the Rodgers Commission recommendations. At that time, KSC management instituted a centralized S&MA structure with over 300 personnel reporting to the Director of SR&QA, split among Quality, Safety and Reliability, and Mission Assurance. This directorate contained a trending division and a quality engineering division. By 1995, the QA directorate was staffed by approximately 180 people. In 1999, this was down to 120 with 6 people on special assignment. So although eroded, this type of structure remained in place until April 2000, when KSC management decentralized the S&MA function and a new philosophy was used to perform the quality function. In keeping with the program move to performance-based contracting, S&MA functional line responsibility was moved to the program, and the Safety, Health, and Independent Assessment (SHIA) Directorate was created, which would provide an independent safety and mission assessment capability as part of its functions. The S&MA organization within the program had three distinct reporting paths depending on the type of data and function—SSP, KSC S&MA Directorate (SHIA), and NASA Headquarters OSMa.

The KSC SHIA Directorate provides a consistent S&MA interface to NASA Headquarters and other NASA Centers. SHIA coordinates and interprets Center and Agency policy and requirements, and formulates

Center S&MA policy and requirements as a flow down from the Agency level. Additionally, the directorate provides S&MA discipline subject-matter experts that serve as Center focal points for S&MA issues and actions.

The Associate Director of S&MA, within SHIA, provides leadership in the planning, organizing, and implementing of the S&MA disciplines within the various KSC organizations. The organizations are wholly responsible for the performance of S&MA functions for the program. The Associate Director of S&MA is also responsible for the independent assessment of the programs' execution of the policy and adherence to their own program S&MA processes.

From 1996 to 1997, the Space Flight Operations Contract (SFOC) was leased with the intent to move toward privatizing Shuttle operations. NASA management instructed KSC to develop a process to reduce GMIP's and Government oversight in light of the performance-based contract. KSC presented a proposal for a reduction mechanism consistent with NASA's role, transitioning from oversight to insight. A letter issued by the SSP Program Manager authorized the effort and stated, "The review will result in an evaluation of GMIP's and the development of program recommendations for retention, modification, or deletion on a case-by-case basis." Additionally it stated, "This review is consistent with the Space Shuttle Program's requirement of transitioning NASA from oversight to insight."

Over the past 18 years, GMIP volume and scope changed significantly with an initial substantial increase post-Challenger followed by several years of phased and evolutionary reductions in quantity and scope.

From 1986 (post-Challenger) to 1989, there were approximately 44,000 GMIP's per flow for the SSP at KSC. At this point, a change to a more risk-based approach resulted in an evolutionary reduction of GMIP's. This approach also established a "witness or verify" GMIP designation. Process steps could be verified after completion rather than witnessed real time. In 1993, KSC instituted a structured inspection process that incorporated a risk-based approach, sampling, and other surveillance techniques. These changes, coupled with an OMRSD review, resulted in a reduction of GMIP's to approximately 22,000 per flow by 1995. This structured inspection approach was focused on establishing a different process for Criticality 2 and 3 inspections. Criticality 2 and 3 inspections were then only verified by the Government through sampling.

In 1996, as a part of the reduction approach, a KSC S&MA and SSP team established a set of criteria based upon a consensus within KSC quality and engineering communities with approval from the appropriate design center. The following criteria was known as the "litmus test:"

1. criticality 1/1R hardware assembly task, which if done improperly, could reasonably lead to a loss of vehicle or mission, and for which there is no subsequent nondestructive evaluation (NDE) or functional test (e.g., gap check or leak check), which provides confidence that the assembly is proper; and
2. the last functional test of a criticality 1/1R flight or ground support equipment (GSE) system or subsystem, which verifies that the system or subsystem is operational and ready for flight.

The litmus test was updated in 1998 and changed to:

1. a Criticality 1 Hardware Assembly Task, for which there is no subsequent NDE or functional test planned, which provides confidence that the assembly is proper; or
2. the last test of a Criticality 1 Flight System or GSE System, which provides confidence that the system is operating as designed and within specification.

From 1997 to 1998, there was a significant KSC GMIP reduction based on further refinement of the risk-based approach. Existing GMIP's were evaluated for retention using the litmus test. After this review, GMIP volume was reduced to approximately 8500 per flow. Subsequent QPRD changes have resulted in an increase of KSC GMIP's on electrical system elements in response to wiring concerns from STS-93.

## 2.5 GMIP History—External Tank (ET)

The pre-Challenger ET GMIP program consisted of approximately 970 total inspections. Following the Challenger accident, NASA significantly increased the ET Government inspection program in 1990 to approximately 5000 GMIP's. That number remained in effect until a joint NASA/Defense Contract Management Agency (DCMA) Plant Representative team reduced GMIP's to approximately 3,771 by driving inspections to the last opportunity assurance point in the process (i.e., shakedown, proof test, acceptance test, etc.). Between 1995 and 2000, NASA categorized the existing GMIP's and then eliminated one category at a time in a phased approach, further reducing ET GMIP's.

The ET categories were:

1. non-CIL/low-value/paper reviews,
2. redundant contractor or Government inspections,
3. process stability/high confidence,
4. progress toward stable/United Space Alliance transition, and
5. high-risk in-family/critical last opportunity.

Results of the review left the number of GMIP's at 228. In FY 2000, some GMIP's were reinstated as a result of process reviews, along with hardware and tank-handling risk assessments. This brought the number of GMIP's currently performed to 586.

### 3. Assessment Methodology

NASA's Quality Assurance (QA) Programs in place today at the KSC (Shuttle processing) and at the MAF (External Tank assembly) are relatively good based upon the ground rules that were in place when the programs were formulated (see GMIP Reductions and Premise Base section). The IAT did not perform its assessment against those ground rules, but rather the new set that resulted from the Columbia accident and the subsequent CAIB Report. This premise base is as follows.

- The Space Shuttle is a developmental vehicle that is also an aging vehicle.
- The Shuttle must function for at least another decade.
- The Space Shuttle Program is a relatively high-risk program.
- The NASA QA Program must ensure both safe hardware and an effective contractor quality program.

The IAT met August 11–15, 2003, at the KSC to be briefed on the scope, timing, and necessity of their pending assessments. They also developed team ground rules and norms at this initial meeting. During follow-on meetings, the team received briefings from KSC Shuttle processing program managers and MAF (External Tank) S&MA management on their QA Programs with specific focus on the GMIP process. The Team conducted site visits at the KSC and the Michoud Facility to evaluate production and assembly operations, quality flow documentation, and GMIP application, and met with quality assurance personnel on the floor. The Team held discussions and document reviews with S&MA personnel at both locations. The IAT evaluated sample processing/assembly plans, processes, and procedures at KSC and the MSFC MAF to examine QPRD and MID effectiveness and the application of required GMIP's. The Team reviewed selected existing SSP quality program assessments and audits to determine the status of the quality program elements over the past decade. The IAT met with all levels of management during these site visits, which included NASA program management, S&MA management, NASA QE and QAS's, and contract S&MA management personnel. This allowed evaluation of daily quality tasking and workforce technical capability. The IAT also reviewed training programs at KSC and MAF.

The Team formed two subteams to look at each area in more depth. The subteams held further discussions, briefings, inspections, document reviews, and workpaper reviews at each location. The subteams also performed job shadowing; limited database review; workpaper review of a small subset of Shuttle processing; MAF assembly for GMIP adequacy against documented criteria (QPRD and MID); and other reviews that touched on quality systems or GMIP's reviewed.

The subteams consolidated the information and created recommendations and observations. The GMIP Final Report narrative was drafted from the proposed findings, recommendations, and observations developed by the subteams. Based on requirements received from the Associate Administrator for S&MA, the report also contained a facts element as well as the traditional findings, observations, and recommendations. This was to help provide a logic flow as to how the GMIP IAT developed the recommendations.

The following sections that document the IAT's evaluation of the GMIP policy, process, and workforce include facts, findings, observations, and recommendations regarding all elements of the Shuttle quality program for the Orbiters at KSC and the ET at MSFC MAF.

Recommendations that are accepted from the entire report will be dispositioned by the RTF Planning Team. The Team noted that there were, and are, SSP and Code Q activities taking place to address many of the issues found by the Team. These activities range from reviewing all processing surveillance plans to aggressively pursuing the hiring of S&MA personnel.

## 4. GMIP Assessments— Policy, Process, and Workforce

### 4.1 NASA GMIP Policy

The responsibilities that drive GMIP's begin with the FAR, which establishes a fiduciary responsibility and provides for Government contract QA, when necessary or beneficial to the Government.

NASA Code Q issued policy in the form of guidelines to help programs properly apply contract QA. The IAT reviewed this NASA policy relating to GMIP's and general QA activities. NPG 8735.2, Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts, defines insight and oversight, risk elements, and items that should be considered for mandatory action. The programs further define their quality plans, which for the SSP consist of:

1. NSTS 07700 Volume 11—Shuttle Integrity Assurance Plan  
(covers FMEA/CIL, Problem Reporting and Corrective Action (PRACA), HA, etc.),
2. NSTS 07700 Volume 10—Master Verification Plan  
(provides the philosophy on verification including use of inspection), and
3. NSTS 5300.4 1D-2—Safety, Reliability, Maintainability, and Quality Provisions for the Space Shuttle Program (covers the process of contractor inspection).

The following three tables include the IAT's facts, observations, and recommendations on NASA policy as they relate to GMIP's and QA Programs.

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#### NASA POLICY 1

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##### **FACTS:**

1. The IAT, as part of the Independent Assessment of the Government Mandatory Inspection Points (GMIP's), reviewed the overall QA Program and the NASA top-level QA documentation to determine its adequacy in establishing requirements.
2. NPG 8735.2, Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts, does not provide direction for planning and implementation of QA activities by NASA personnel, but does provide guidance for QA activities by delegated parties.
3. NPG 8735.2 provides direction to "consider" including elements, but very little direction for the inclusion of elements of a QA Program.

##### **OBSERVATION (STRENGTH):**

- NPG 8735.2 provides comprehensive guidance for delegated NASA QA activities, with general recommendations for areas of focus (e.g., major hardware moves).

##### **OBSERVATION (WEAKNESS):**

- The IAT determined by analysis, comparison with other programs, and best practices that the NASA policy (NPG 8735.2) does not provide sufficient guidance on the requirements for a comprehensive NASA QA Program. The policy provides information on the scope and nature of Government contract quality activities, but does not provide sufficient direction on planning and implementation of the activities by NASA personnel.



**RECOMMENDATION:**

- Revise NPG 8735.2, Management of Government Safety and Mission Assurance Surveillance Functions for NASA Contracts, to define the QA Program elements that must be included in a comprehensive QA Program. These elements would include Government mandatory actions, process monitoring and validation, data gathering and analysis, quality system audits, and supplier QA.

## NASA POLICY 2

**FACTS:**

1. An IAT review of NASA policy documentation found there were no policy or standards documents focused on GMIP's.
2. IAT discussions with NASA personnel revealed that different program elements (Orbiter, External Tank) define GMIP's differently.
3. There was a draft GMIP standard prepared for release in 1997.

**OBSERVATION (WEAKNESS):**

- The GMIP policy documentation is inadequate.

**RECOMMENDATION:**

- Revise and issue the GMIP standard to include the GMIP technical criteria, addition/deletion process, periodic evaluation, data gathering, and analysis functions.

## NASA POLICY 3

**FACTS:**

1. The primary documents used to determine GMIP's are the FMEA's/ CIL's, HA's, and the OMRSD.
2. Discussions with NASA personnel indicate data from assessments, audits, and nonconformance data are generally not fed back into processes, including FMEA/CIL and HA reviews.
3. Selected critical FMEA's/CIL's and HA's are undergoing review by SSP.
4. The IAT found no process which directed or provided a requirement to review FMEA's/CIL's and HA's periodically to challenge assumptions and incorporate knowledge from GMIP's and other quality and processing data. FMEA's/CIL's and HA's are updated with design changes.

**OBSERVATIONS (WEAKNESS):**

- FMEA's/CIL's and HA's which do not undergo periodic review or update using processing data feed-back can lead to stale GMIP's which are not optimized.
- This lack of data feedback makes it more difficult to challenge the original FMEA/CIL assumption sets when performing these reviews.

**RECOMMENDATIONS:**

- Perform a periodic or phased review of FMEA's/CIL's and HA's.
- Use processing and performance data to help validate or challenge assumptions.

**Example:**

Selected critical FMEA's/CIL's and HA's could be reviewed on a regular basis (e.g., biennially), while all critical FMEA's/CIL's and HA's are reviewed on a longer-term basis (e.g., quadrennially). These reviews would evaluate the basic assumptions used to perform the analysis and challenge their validity.



Additionally, processing and performance data should be used to help validate or challenge the assumptions and the resulting product (CIL).

## 4.2 GMIP's at Kennedy Space Center

### 4.2.1 KSC Shuttle Processing GMIP Policy

The top-down quality system is codified through the Kennedy Documented Processes (e.g., KDP-P-0008, KDP-P-0016).

At KSC, the GMIP activity is governed by the QPRD. The QPRD is a NASA document that is maintained by the Shuttle processing contractor. The IAT randomly selected a subset of Shuttle process flow documentation to determine the adequacy of the QPRD documentation and GMIP criteria. The coding (i.e., application) of GMIP's into the work documentation based on the existing QPRD criteria was determined adequate. However, the IAT determined that the addition or deletion or update/change of a GMIP is not controlled by a documented process. The number of GMIP's for any given flow is not known. Individual GMIP's are not tracked, and comprehensive data are not taken on the GMIP activity. Work Authorization Documents (WAD's) are reviewed to ensure all operations, including GMIP's, are performed, but it is difficult to determine if a GMIP experienced problems prior to being performed or was even coded into the workpaper. The QAS's have noted great difficulty in processing their requests for GMIP changes. The IAT also noted that GMIP's are not placed into the flow based on a periodic review of the GMIP's or from data relating to contractor process/system stability/control.

The quality program for the Shuttle processing, definitions of quality systems assessments, process validation and analysis, and the GMIP's are well documented in the KSC Business System (<http://businessworld.ksc.nasa.gov>). Elements of the NASA quality effort to ensure the SFOC contractor quality are defined. GMIP's, at KSC and the MAF, are defined as insurance actions required to be in place to ensure the safety of flight.

The following four tables include the IAT's facts, observations, and recommendations on KSC policy for Orbiter processing.

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### KSC POLICY 1

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#### **FACTS:**

1. The IAT reviewed many of the KDP's to determine how well the KSC quality system policy is documented.
2. KDP-P-0008, Shuttle Processing Surveillance Plan for the SFOC, states that surveillance shall be performed per KDP-P-1693. KDP-P-1693 invokes KDP-P-0008 as one of its key process documents.
3. KDP-P-0008 deals specifically with the overall expectations of the QA function.
4. KDP-P-0010 0012, 0016, and 0017 flow out of 0008 as surveillance implementation plans for Engineering, Shuttle Processing Logistics, S&MA, and the Shuttle Project Office.
5. The Shuttle Processing Safety & Mission Assurance Quality Plan, document KDP-P-1812 Revision Basic, has been developed and is currently in the approval/signature process.
6. There are no Data Requirements Descriptions (DRD's) assigned to KSC Shuttle S&MA, and therefore none are listed in KDP-P-0008. However, there is a Letter of Delegation from the SSP S&MA manager that defines contractor performance and technical evaluations required from the KSC S&MA organization.

7. There is a list of the elements that can be used in a comprehensive QA Program in Appendix A of KDP-P-0008.
8. The KSC Shuttle S&MA organization has initiatives in work to address some of the issues outlined in this report. In particular, a GMIP review team has been formed to develop a permanent change process and a more flexible temporary change process. This team will also work with systems engineers to reevaluate the requirements of the QPRD on a system-by-system review and then establish a periodic review cycle for the QPRD. In addition, KSC Shuttle S&MA is instituting a pilot program to collect GMIP accept/reject data as part of a more comprehensive QA Program that includes hardware and process/procedure surveillance.

**FINDING:**

- KDP-P-0008 and KDP-P-1693 do not provide clear lines of authority and requirements (they cross-reference each other).

**OBSERVATION (WEAKNESS):**

- While elements of the quality plan are documented in KSC policy, there is no overall quality plan that defines a comprehensive QA Program, including Government and contractor programs. In its current form, KDP-P-1812 is insufficient to define a comprehensive quality plan.

**RECOMMENDATIONS:**

- Continue to develop a comprehensive, integrated KSC Shuttle QA plan based on NASA's new environment and premise (the new premise base is in the Assessment Methodology section).
- Review and revise KSC QA documentation to clarify authorities and requirements.

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## KSC POLICY 2

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**FACTS:**

1. GMIP reductions were performed against criteria called the litmus test.
2. GMIP activity is governed by the QPRD.
3. The IAT reviewed the QPRD for adequacy, content, and usability.
4. The IAT reviewed the litmus test used for the last major GMIP reduction.
5. The GMIP criteria are not formulated to address potential schedule impact.
6. The QPRD is a NASA-/contractor-developed document that is maintained by the Shuttle processing contractor.
7. The QPRD does not cover major moves (e.g., GMIP's are not in place for Vehicle Assembly Building (VAB) lift and mating of the Orbiter to the ET). It calls for very limited coverage of TPS repair and installation.
8. QAS's expressed concern over limited GMIP's on Reinforced Carbon-Carbon (RCC) procedures, stating that RCC is mostly Surveillance Inspection Point (SIP) controlled, as many of the RCC activities are new to KSC or are being modified based on new nondestructive evaluation (NDE) requirements.

**OBSERVATIONS (WEAKNESS):**

- The QPRD is weak for some tasks typically associated with high-risk operations (e.g., major moves, TPS, RCC frame assembly).
- The QPRD is also weak in the area of unfamiliar, new, or first-time requirements (e.g., OMM, flow liner installation, RCC buildup, SSME shop).
- The current GMIP's are inadequate to ensure integrity of some critical processes (e.g., RCC frame assembly).

- In some cases, the adherence to placement of GMIP's at the last point of the process/assembly does not allow complete inspection of all critical items.
- Requirements for GMIP's do not consider the impact of schedule delay from finding a problem later in the flow. This can impact long-term cost and system availability (which could result in substantial loss to the Government).

**OBSERVATION (STRENGTH):**

- The GMIP reductions were based on a logical and consistent process that was approved by the program.

**RECOMMENDATIONS:**

- Perform a comprehensive review of the QPRD/GMIP requirements, beginning with the emerging results of the current SSP FMEA/CIL/Hazards review.
- Assess adding schedule impact as a GMIP criterion to prevent finding problems late in the flow.
- Develop appropriate critical process-based (e.g., TPS installation, major moves) FMEA's/CIL's (or similar analysis) in addition to the hardware FMEA/CIL update activity under way by the SSP.

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## KSC POLICY 3

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**FACT:**

- The IAT randomly selected and reviewed a subset of Shuttle process flow documentation to determine the adequacy of the GMIP process using the current QPRD criteria.

**OBSERVATIONS (STRENGTHS):**

- GMIP placement met QPRD requirements.
- The IAT determined that the application of GMIP's into the work documentation was adequate, based on the existing QPRD criteria.

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## KSC POLICY 4

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**FACTS:**

1. The IAT held discussions with many QAS's on their use of SIP's and their ability to add GMIP's.
2. Many QAS's expressed frustration with the difficulty in adding or changing GMIP's.
3. The contractor sections of the QPRD (which controls the Designated Inspection Points) can be changed without NASA's knowledge or approval. Note: The QPRD update, issued September 15, 2003, resolves this problem.
4. There does not appear to be a formal, logical GMIP change process, according to discussions with numerous Government personnel.
5. There is no specified periodic review cycle for the QPRD.
6. Due to the difficulty in adding GMIP's, many QAS's use SIP's instead.
7. Discussions were held with many Government employees on the philosophy of GMIP's, and when they should be added or deleted.
8. Many QAS's expressed a desire for all Criticality 1/1R items to be listed in the QPRD with an exception list of specific items not requiring Government inspection.

**OBSERVATIONS (WEAKNESS):**

- There is no formal process for changing the QPRD or adding GMIP's based on metrics, feedback, or requests.
- Adding GMIP's is exceedingly difficult, as the QPRD is not a flexible, responsive document.
- The current philosophy for GMIP additions seems to be: "prove why an inspection should be performed and where it is in the QPRD."
- There is no specified periodic review of the QPRD or baseline GMIP's to determine their adequacy.

**RECOMMENDATIONS:**

- Continue to define and implement formal, flexible processes for changing the QPRD and adding, changing, or deleting GMIP's based on metrics, feedback, and requests.
- Implement a periodic review process of the QPRD to assure GMIP effectiveness and address trending and analyze feedback, lessons learned, changed environment, etc.



*Figure 2.*  
The Orbiter Columbia being moved to the Vehicle Assembly Building for External Tank mating operations.



*Figure 3.*  
The Orbiter Columbia rolls out of KSC's Orbiter Processing Facility Bay 3.



#### 4.2.2 KSC Shuttle Processing GMIP Processes

The IAT evaluated the Shuttle processing quality program in place at KSC, with emphasis on the GMIP activity. The GMIP activity is performed by NASA QAS's in accordance with the QPRD. Typically, 30 minutes prior to GMIP performance, the QAS staff is notified to ensure their availability so as not to interrupt flow and to allow their involvement in the process. According to IAT discussions with QAS's, they appear satisfied with the GMIP application procedures and the QPRD documentation; however, the change process is lacking. Some QAS personnel expressed opinions that earlier versions of the QPRD were more definitive. These QAS employees also said there had been few changes since the approximately 8500 GMIP total was established (the electrical wiring was the only major GMIP change).

A Surveillance Inspection Point (SIP) is a temporary GMIP that may be stamped into the work documentation by a KSC QAS. The SIP's are not formally documented—just as there is no formal documentation process for GMIP application. Currently there are no effective metrics that can be used to determine the effectiveness of the NASA and contractor Quality Assurance Program.

The IAT also reviewed other elements of the quality program. The process validation and analysis activity that would be performed by the QAS's when not involved with GMIP's does not occur. NASA KSC SSP depends on the random inspection and sampling activity of the contractor to cover this area and has no coverage within their quality program. The system provides some process information; however, the true random nature and comprehensiveness of the database and analysis result in questions regarding the accuracy of this process to ensure process stability. The quality system assessment element of the NASA quality function is provided by the NASA process analysts (PA's), who are composed mostly of former QAS's. These PA's perform assessments as deemed necessary by a NASA quality engineer (QE). These assessments can come from the QAS request for evaluation of an area, nonconformance, or process concern. There are a limited number of audits performed due mainly to the lack of QE and PA workforce. The slow response of the system to audit requests has caused many QAS concerns to go unreported.

The NASA QE function appears to be understaffed. There is seldom a QE on the floor for support when the QAS staff is applying GMIP's. They also are not proactively involved in QPRD revisions and do not support nonconformance closeouts or Material Review Board dispositions. QE analysis of process flow and nonconformance data could be pivotal in determining and maintaining the appropriate levels of effort in each of the elements of the NASA quality program.

The history of databases for GMIP information is unclear. A Quality Surveillance Record (QSR) database that was replaced by the current S&MA Reporting Tool database (SMART, an electronic file cabinet) was repeatedly referenced by QAS personnel. Discussions indicated that the Orbiter logs for liquid spills and areas of structural corrosion were stopped in 2000. This information substantiates the weak or nonexistent metrics and trending capability for GMIP activity.

The following seven tables represent the IAT's facts, observations, and recommendations on KSC Shuttle processing.

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## KSC PROCESS 1

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### FACTS:

1. QAS's demonstrated a consistent understanding of the GMIP process.
2. Most QAS's are very experienced and have indepth knowledge of the processes they are inspecting.

### OBSERVATION (STRENGTH):

- QAS personnel have a common understanding of the GMIP process and have the experience needed to perform their work.

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## KSC PROCESS 2

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### FACT

- It is not evident to the IAT that the QAS staff uses any published processes/procedures documentation (similar to a Standard Practices Instruction (SPI) or work instruction) to assure consistency in day-to-day processes and collateral tasks necessary to accomplish the total GMIP function.

### OBSERVATION (WEAKNESS):

- The performance of GMIP's appears to be based on tacit knowledge rather than codified methodology.

### RECOMMENDATION:

- Update and issue GMIP process and procedure documentation to provide complete definition and clear requirements, including monitoring, data acquisition and recording, and feedback to management.

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## KSC PROCESS 3

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### FACTS:

1. There is no integrated closed-loop Management Information System (MIS) that clearly defines database content. Additionally, no MIS exists that can be used to analyze workforce performance and staffing requirements.
2. All KSC nonconformance paper has a requirement to complete a "cause code" data field that can be used for trending and other applications. KSC has a history of contractors using this field incorrectly. A recent PRACA assessment (JS-2005) reflected over 20-percent error in cause codes in the areas of workmanship and process errors, both of which are critical to trending of safety and quality-related problems.
3. Most QAS personnel stated that the SMART database, used to record the results of their inspections, was not used by many QAS's. QE's, PA's, and S&MA management also stated the SMART database was not used for tracking or trending GMIP data.
4. The IAT found several QAS/PA personnel who had developed ad-hoc surveillance plans and databases.
5. The validity of inspection result databases has been challenged by some for several reasons—consistency of inspector reporting, changes in processes, sample size, randomness of inspections, and perceived lack of data review.
6. Current Orbiter PRACA system requirements (NSTS 37325) allow vendor latitude in reporting Acceptance Test Procedure (ATP) anomalies.
7. Several attempts have been made in the past years to incorporate a more thorough QA Program that includes better data collection and tracking.

8. Many QAS's stated that in many cases, when a QAS finds an error that the contractor QC missed, the QAS will have the QC write up the error. If an error found by a QC or a QAS can be fixed on the spot, it is often fixed without any recording of the error. Additionally, if an issue is identified by a QAS before it occurs, it is never reported, tracked, or trended.

**OBSERVATIONS (WEAKNESS):**

- There are many MIS databases of varied usefulness and functionality used at KSC. Most are lacking either the capability or data integrity to enable trending and analysis of GMIP data. This makes GMIP assessment and tracking very difficult.
- Comprehensive data are not taken on individual GMIP activity. The KSC GMIP database (SMART) is at best an electronic file cabinet. The nonconformance databases are not complete or accurate due to cause code issues. Cause codes are not used or are used inconsistently and incorrectly when documenting nonconformances into the various databases.
- Internal resistance to trending and analysis coupled with mutual distrust has led to a rationalization by KSC QA management as to why database information cannot be used. This seems to have sidelined important opportunities to gather data and then analyze and feed results back into the processing, quality, logistics, and design systems.
- "Close call" and "caught before occurred" issues are not identified, recorded, or trended. This loss of data provides an incomplete picture of process stability and health.

**RECOMMENDATION:**

- Assess all available Shuttle processing QA performance metrics information data sources/bases. Expand, combine, and enhance them as necessary to produce a complete and integrated MIS, as part of their comprehensive QA Program, which can be used for closed-loop trending, problem identification, and resource allocation.

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## KSC PROCESS 4

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**FACTS:**

1. With the advent of the SFOC, NASA SSP outsourced their processing of the Orbiter to include quality functions that were traditionally maintained by NASA.
2. The number of GMIP's per flow has been significantly reduced since the post-Challenger time-frame.
3. There is no closed-loop GMIP tracking.
4. KSC QA management personnel stated the actual number of GMIP's for any given flow is not specifically known.
5. Process audits are limited in number and in nature; although they are reported to be improving relative to the last few years.
6. Trend analysis, structured process monitoring, and procedural compliance verification are not being performed by the QAS workforce and are limited overall.
7. The current quality program was initially derived based on a "going to privatization—zero GMIP's" philosophy.
8. The local program elements successfully fought to retain critical quality elements including GMIP's.
9. During reviews and discussion it became apparent, and was acknowledged by KSC S&MA management, that there is a need to develop a total QA activity that includes all attributes of a comprehensive program including inspections, assessments, and audit functions.
10. During reviews and discussion it became apparent, and was acknowledged by KSC S&MA management, that NASA's QA Program does not adequately evaluate the contractor's QA Program.



11. Suppliers or vendors represent hundreds of sources of hardware for SSP elements. NASA SSP has the responsibility to oversee the supply base to ensure that all contractual requirements are being met and that the product delivered conforms and is safe for operation.
12. Some QAS personnel expressed concern over the documentation accompanying vendor hardware as well as uncertainty as to the currency of USA audits of the various vendors.

#### **OBSERVATIONS (WEAKNESS):**

- There is no comprehensive NASA QA Program in place.
- KSC's QA Program is focused primarily on finding errors in the Shuttle processing, with little attention focused on how well the contractor's QA Program is functioning. Most of the effort goes toward process inspections through GMIP's and SIP's, with little effort going toward other important elements such as independent process audits and assessments, data collection, and data trending.
- The independent process audits and assessments currently being performed on the contractors and their suppliers are inadequate. Outsource quality standards must be maintained through regular and comprehensive audits and surveillance.
- There is no closed-loop accounting of GMIP's by the Government (workpaper incorporation, performance, paper closure).
- As the actual number of GMIP's for any given flow is not specifically tracked and analyzed, how the current GMIP set is affected cannot be determined. Assessments for typical GMIP's per flow range between 8500 and 10,000 GMIP's.
- Work Authorization Documents (WAD's) are reviewed to assure all operations, including GMIP's, are closed, but it is very difficult to rapidly determine if an inspection point was performed or experienced problems before closure.
- It appears from briefings and discussions that the level of effort of the NASA KSC QA Program is based primarily on the size of the reduced QA workforce, rather than on an estimate from the ground up of the resources and structure necessary to implement a comprehensive safety and quality program.

#### **OBSERVATION (STRENGTH):**

- The local program element successfully fought to retain critical quality elements including GMIP's.

#### **RECOMMENDATIONS:**

- Develop, document, and implement a comprehensive QA Program that includes:
  1. a full range of QA functions (e.g., trending and analysis, audits, process mapping, process monitoring, process validation, mandatory assurances, training, material review, etc.) for the Space Shuttle elements themselves and the contractor's QA Program;
  2. a process and tool set for data collection, trending, analysis, and feedback process, including results of GMIP's;
  3. emphasis on the effectiveness of the contractor's QA Program;
  4. assessment and use where applicable of commercially available toolkits/benchmarking and best practices that can be readily adopted and help facilitate cultural change (for cultural change see Workforce Section);
  5. the minimum skill mix necessary to accomplish the total QA function and assure that critical mass is in place (The balanced distribution of these activities should be based on the characteristics of the contractor's QA Program (along with process control data), the MIS effectiveness, the criticality of processes, and the individual hardware items.); and
  6. a more rigorous system for choosing and implementing cause codes used for the nonconformance paper.
- Assess developing a process to ensure that GMIP's are being incorporated into workpaper, performed, and their workpaper closed (including temporary GMIP's).
- Assess USA's vendor audit plans and performance on a regular basis to assure compliance with QA requirements and to review ATP anomalies.

- Adapt quality requirements to address supplier activity in the following areas:
  - compliance with the FAR,
  - process certification/verification (to include production, quality, engineering, etc.), and
  - product conformity to prime contractor procurement documentation.

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## KSC PROCESS 5

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### **FACTS:**

1. The in-family/out-of-family designator was established to prioritize the workload associated with nonconformance resolution.
2. Several individuals expressed concern over the in-family/out-of-family designator being interpreted differently by various groups; it is a source of confusion.
3. KSC allows USA to assign the designators. Misuse of this protocol could mask significant problems from NASA insight.
4. The IAT is concerned that recurring anomalies that should get higher attention due to their frequency may get less attention due to being placed in the “in-family” category.

### **OBSERVATION (WEAKNESS):**

- The in-family/out-of-family designator is confusing and does not appear to add value to a thorough investigative process. Subjugation of a failure without thoroughly understanding the cause or frequency of occurrence can lead to an incorrect understanding of its criticality and impact.

### **RECOMMENDATION:**

- Eliminate or clarify the in-family/out-of-family designator.
  - If retained and clarified, ensure NASA makes the final determination on classification and that recurring items receive appropriate attention.

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## KSC PROCESS 6

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### **FACTS:**

1. The IAT found concern and varying opinions among NASA personnel over the terms “insight” and “oversight.”
2. The IAT believes that the use of simple one-word terminology to define how the Government watches over contractor processes has caused confusion in the QA workforce.

### **OBSERVATIONS (WEAKNESS):**

- The distinction between insight and oversight is not well defined or not well understood by most QA workers at KSC. In discussions with the Government workforce, the terms were often reversed or used interchangeably. The terms were, however, often referred to as the “bad one” and the “good one.”
- One-word definitions fall short of satisfying the need for a clear delineation of the “watch” criteria chosen for each particular element.
- The confusion over term definition has become a rallying point for disgruntlement among those opposed to NASA’s reduction in QA activities.

**RECOMMENDATION:**

- Consider eliminating “insight” and “oversight” in the quality arena and simply determine what level and type of QA methods are to be used in each area. Those making the decision should then explain why that particular level and type were chosen.

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## KSC PROCESS 7

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**FACTS:**

1. The USA work control documents used on site are consistent and familiar to working personnel.
2. Occasionally work or kit installations from Boeing or the NSTS Logistics Depot (NLSD) come to the floor on different workpaper.
3. KSC uses the USA/Boeing Configuration Verification Accounting System (CVAS) as a source for current drawings when reviewing WAD’s. A deferred work item may be planned to an earlier release of the system drawing.

**OBSERVATIONS:**

- Some QAS personnel expressed concern over workpaper from Boeing for the OV 103 OMM and workpaper from the USA NSTS Logistics Support Depot (NLSD) being different from the KSC WAD’s. The two sets of workpaper exacerbate the reportedly busy QAS work schedule. This is primarily a nuisance but has the potential to be a more critical problem.
- Some mod kits are tied to an older drawing release. This is a problem with the USA/Boeing CVAS.

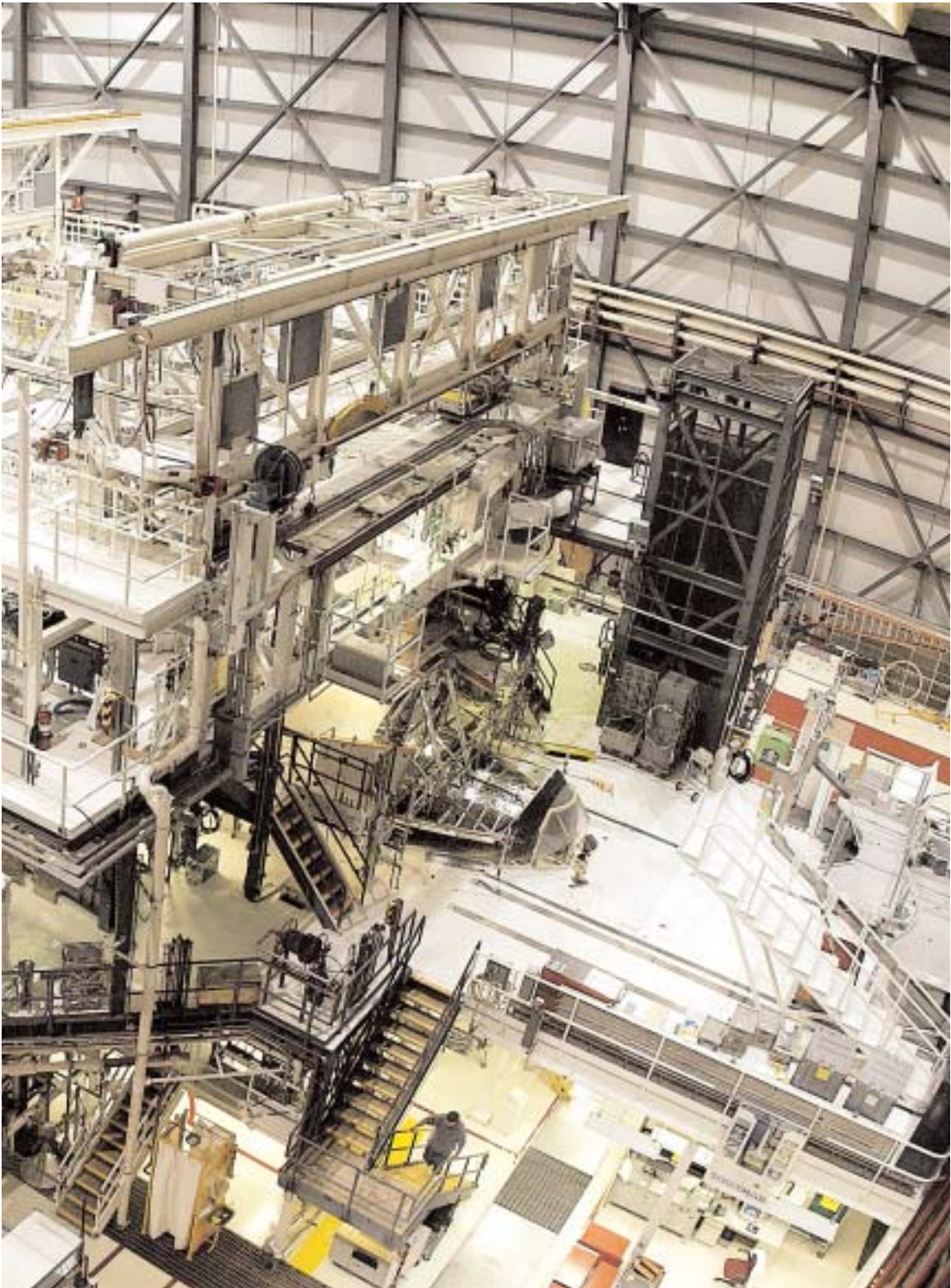
**RECOMMENDATIONS:**

- Assess and take corrective action on workpaper disparity issues.
- Work with the Boeing Launch Services Contract to reconcile CVAS issues.



*Figure 4.*  
The Orbiter Columbia lifted into High Bay 3 in the Vehicle Assembly Building.





*Figure 5.*  
The platforms and equipment required for processing an Orbiter in the Orbiter Processing Facility.

### 4.2.3 KSC Shuttle Processing GMIP Workforce

The NASA KSC workforce involved in quality activities is comprised of inspectors (QAS's), QE's, PA's, and system engineers (SE's), and is supported by discipline engineers at the design centers. The hands-on workforce includes contractors—predominately the USA consortium. All of these parts must work together to forge an effective system. Criteria are established in the QPRD and agreed to by the contractor. The contractor incorporates GMIP's into the workpapers. The QAS's perform the inspections, and the QE's and SE's deal with issues and new work. The QE's also plan or assign work to the PA's. When all GMIP's have been performed, the contractor checks to make sure all steps in the work document are closed and stamps the document as closed, thus also closing the GMIP. There seems to be a strong cultural bias within the KSC workforce that QAS personnel are “cops” (both contractor and NASA), rather than someone who can help make sure it is safe to fly.

The number of QE employees is limited, and they do not spend much time on the floor. Although the QAS workforce is much larger, it has been limited by NASA KSC QA management to performing inspections only. The QAS's report that some of the inspections are frustrating as they no longer permit a QAS to ensure an inspection point “end to end,” and for a “ready to install” GMIP, that initial look may be all the QAS is allowed to see and stamp. The QAS has to trust that a test farther down the line will ensure that the installation was performed correctly, which creates a dilemma since the QAS's prefer to see the job through to closure. Most QAS's remain in the area unofficially until they see the installation is complete. The human element seems to have been overlooked in much of the GMIP reduction effort.

Although the SSME element was not part of the GMIP assessment charter, the IAT performed a high-level look at KSC QAS activities in the SSME shop located at KSC.

The following seven tables contain the IAT's facts, observations, and recommendations on the KSC workforce issues.

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## KSC WORKFORCE 1

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### FACTS:

1. Based on discussions and observations, the QAS's are devoted to ensuring the safety of the Shuttle through their inspections.
2. The QAS's report that they rarely see QE's, PA's, or SE's in the work area (floor) of the VAB or Orbiter Processing Facility (OPF).
3. Many QAS's expressed concern over lack of support from Quality Engineering and regard the PA function as non-value added.
4. Many QAS's do not seem to appreciate the importance of collecting data, or believe that they were ordered not to collect data, on the errors they discover.
5. The QAS staff viewed the 22,000 to 8500 GMIP reductions as a job threat. The unstable environment of changing job responsibilities and the QAS feelings of being unappreciated magnified this negative perception. The ZBR exacerbated the problem when management announced that GMIP's were soon going to zero. In recent years the SSP has recognized its QA responsibility will not allow the inspector workforce to go to zero, but has not clearly articulated to the workforce what the Shuttle Program responsibility is, even though it is codified in published KSC documentation.
6. DCMA personnel are accomplished at performing structured process monitoring, procedural compliance verification, and audit functions as an integral part of their day-to-day job. The DCMA Web site has training information that might benefit KSC QAS personnel.
7. There is a significant amount of overtime performed on a regular basis, according to discussions with QAS's and their supervisors.

**OBSERVATIONS (WEAKNESS):**

- There are morale and trust issues with the QAS workforce.
- There is currently a dysfunctional relationship between the NASA KSC QAS's, PA's, and QE's. This has been caused by a variety of reasons over time and must be fixed to enable an efficient QA Program. Some of the factors are:
  - small QE workforce, viewed as unresponsive and unavailable by the QAS's;
  - higher pay grade of PA vs. QAS and incomplete understanding of the PA role by the QAS's (Many QAS's thought their pay grade should be GS-12, rather than GS-11. However, currently their main function is performing inspections, which grades out at a GS-11 level.);
  - lack of visibility of the PA's and QE's by the QAS's on the floor;
  - uncertainty of future employment due to past history of downsizing;
  - lack of understanding by many QAS's of the role of data collection and analysis in a successful quality program; and
  - separation of locations of QAS, PA, and QE office space.
- There is a significant amount of overtime demands on QAS personnel—often with very little notice and without consideration of the nature of the task assignments. This adds to the QAS morale issue.
- QAS's have become experienced in inspection functions only.
- The NASA KSC QE workforce appears inadequate under today's operational conditions.

**OBSERVATION (STRENGTH):**

- KSC is currently addressing many of the concerns listed above, and the QAS's have expressed cautious optimism. QAS personnel view the new GMIP Process Review Committee as a positive step.

**RECOMMENDATIONS:**

- Assess the QA workforce requirements based on the release of the recommended updated quality plan and assurance requirements.
- Develop and implement a training program to ensure all personnel are thoroughly trained in their areas of responsibility. Incorporate this program into a QA change plan.
- Show all workers how their work fits into the overall quality program and its importance to flight safety.
- Develop an organization and culture that has good communication, understanding, and respect between the workers carrying out the various functions of a comprehensive QA Program.
- Include training for everyone in the importance of all the various functions and how their individual expertise fits into the overall program, along with a clear understanding of how pay scales relate to expertise and functions performed and what job progression possibilities are available.
- Continue efforts to rectify QAS morale problems (e.g., job security, relevance of their contributions, grade structure, staffing, irrelevant databases, and not being able to effect process changes).
- Evaluate how to best perform trend analysis, structured process monitoring, and procedural compliance verification activities as part of an integrated QA process. Strive to include as much “live from the floor” data as is reasonable.
- Have sufficient QE's on the floor and available to support an efficient QA process. The IAT believes that the need for enough SE's to provide a presence on the work floor also should be assessed. Almost all Government and contractor workers saw this presence as highly beneficial.
- After determining what its QA Program should be, determine the proper workforce it needs to meet those requirements and, if necessary, acquire those people.
- Consider using DCMA contract services as a near-term solution or for surge issues.
- Articulate NASA's approach and commitment to its responsibility and accountability for the safety of the SSP to every level of its workforce.



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## KSC WORKFORCE 2

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### FACTS:

1. Comments from several line and management personnel indicated a perception that reported errors would be used to discipline the technicians or QC's who had missed seeing the errors.
2. Based on discussions, the general QAS protocol is to let the contractor write an Interim Problem Report/Problem Report (IPR/PR), even when the QAS finds an error that the contractor QC missed.

### OBSERVATIONS (WEAKNESS):

- The perception that reported errors would be used to discipline the technicians who had made or missed seeing the errors is an indicator of a management or communication issue. The workforce seems worried about telling the truth.
- The protocol of allowing the contractor to take credit for identifying all nonconformances reduces the ability to assess the contractor's quality system and to identify problem areas. The motivation is commendable (no "black hat," all one team) but not conducive to improving USA performance.
- There are existing error/nonconformance data issues:
  - Good error data encompasses all types of errors, including those made and corrected in real time (or caught before being made).
  - These data are almost impossible to collect if the working culture is fear driven.
  - The culture must not be used to punish workers for making mistakes, but to focus instead on learning from mistakes and then communicating the lessons learned to the other elements.This enables:
  - finding and correcting root causes, and
  - reducing likelihood of reoccurrence program wide.

### RECOMMENDATIONS:

- Develop a culture where workers are encouraged to report mistakes, knowing that the reports will be used to reduce the root causes of the mistakes and not to punish the worker making the mistake.
- Use other agencies' examples to benchmark such a culture change and error-tracking and correction system (e.g., the Patient Safety Program initiated by the Veterans Administration in its hospitals and the Aviation Safety Action Program (ASAP) initiated by the FAA with American Airlines and now used in several commercial airline companies).

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## KSC WORKFORCE 3

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### FACTS:

1. Many new inspections resulting from issues or new KSC processing responsibilities are assigned without being checked by human factors experts to provide performance guidelines (e.g., wiring inspections).
2. The IAT was told during discussions that workers perform wiring inspections for several hours between breaks.
3. The DoD has established standard maximum inspection times and breaks for detailed wire inspections.

### OBSERVATION (WEAKNESS):

- Workers doing wire inspections do not take sufficient breaks to adhere to current accepted practice.

**RECOMMENDATION:**

- Consult with human factors experts to determine work area inspection time limits and what risks are associated with extended work hours for specific inspection functions (e.g., wire inspections).

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## KSC WORKFORCE 4

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**FACT:**

- The SSME shop processes hardware that is managed by MSFC; however, GMIP's and resources are managed by KSC.

**OBSERVATION (WEAKNESS):**

- KSC QAS personnel have not been accepted in the SSME environment, and they are unhappy that the SSME is processed with very few specific GMIP's. This has led to some confusion and tension between the two organizations.

**RECOMMENDATION:**

- Reassess the current QA approach in the SSME shop.

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## KSC WORKFORCE 5

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**FACT:**

- On occasion, technicians from Boeing or subtier suppliers perform Orbiter modification work at KSC.

**OBSERVATION (WEAKNESS):**

- QAS personnel stated that Boeing or subtier supplier technicians do not display or state their training or skill certification upon arrival on the floor.

**RECOMMENDATION:**

- Establish a process to verify the certification level of visiting technicians and make this information available to the appropriate processing personnel associated with the work to be accomplished.

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## KSC WORKFORCE 6

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**FACT:**

- The current method of notifying a QAS that he/she will be needed soon to cover a GMIP is by calling the QAS office; therefore, QAS's need to stay close to the office between GMIP's. At the MAF, inspectors carry beepers to notify them of impending GMIP's. However, beepers, cell phones, and other wireless devices are not allowed in most of the Orbiter processing areas at KSC due to hazards.

**OBSERVATION (WEAKNESS):**

- The need for QAS personnel to stay close to hard-line phones for GMIP activity calls seriously hampers critical perform trend analysis, structured process monitoring, and procedural compliance verification activities.



**RECOMMENDATION:**

- Develop some means to allow inspectors to be notified of an impending GMIP when they are away from the QAS office. Beepers could be used when inspectors are not in areas that prohibit them, but other methods should be developed when inspectors are in areas where wireless notification can't be used.

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## KSC WORKFORCE 7

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**FACTS:**

1. In 2000, the S&MA organization at KSC, including the QA function, was reorganized.
2. The organization changed from a line-direct organization to a distributed organization with a policy and assessment core residing in the SHIA Directorate.

**OBSERVATION (WEAKNESS):**

- The current organization has proven to be less than optimal. The current QA function is not independent of the local program (i.e., it is part of the program management chain). Additionally, the current QA function is not independent of the engineering function that develops or modifies systems. These items could limit the ability of the organization to have true independence and provide meaningful checks and balances.

**OBSERVATION (STRENGTH):**

- KSC has an ongoing organizational assessment to address this issue.

**RECOMMENDATION:**

- Assess and modify the KSC organizational structure to promote true independence and provide a meaningful check-and-balance component. Example: Move the Shuttle S&MA function (with the exception of a core group of S&MA representing and supporting the program) to the Center S&MA organization. Move the Independent Assessment function to an office that reports directly to the Center Director (e.g., Systems Management Office).

## 4.3 GMIP's at the Michoud Assembly Facility

### 4.3.1 MAF ET Assembly GMIP Policy

Post Challenger, GMIP's were redefined by a NASA-led team comprised of NASA/MSFC QE's, a NASA senior S&MA resident representative, DCMA QE, and DCMA QAS's. The Team used the inspections and test defined in the FMEA/CIL and unique hazard controls as the basis for establishing mandatory inspection points. Government and contractor subsystem engineers advised the GMIP Team during the process. GMIP's were established at the latest point in the process that each CIL characteristic intent could be accomplished to ensure all safety critical failure modes received Government oversight. Therefore the Team gave little consideration to process maturity and none to process performance. This activity yielded 3771 GMIP's.

Between 1995 and 2000, GMIP's were reduced to prepare for the implementation of a new programmatic philosophy of "oversight to insight." The plan was to minimize Government oversight and significantly reduce Government QA involvement. The following criteria were established to systematically guide this reduction.

- Category A—Low Value/Non-CIL

Elimination of GMIP's based on paper reviews and non-CIL final acceptance testing activities.

(1997—eliminated 868 MAF inspections and 13 vendor inspections)

- Determination that the available documentation and surveillance could accomplish the same results previously accomplished by GMIP's.

- Category B—Dual Contractor QC or Government

Elimination of GMIP's based on instances of dual contractor inspections or dual Government inspections.

(1997—eliminated 166 vendor inspections, 1998—eliminated 6 MAF inspections)

- Determination that the QC vendor contractor performed the same inspection prior to shipment that the onsite QC contractor performed upon receipt.

- Eliminated the NASA walk-downs/shakedown—performed dually by DCMA inspectors.

- Category C—Process Stable/High Confidence

Elimination of the GMIP's based upon a stable process or high confidence in the process and the ability of easy detection of defective parts.

(1998—eliminated 1953 MAF inspections)

- Category D—Keep until Transferred to USA

- a) Category D1—Progress Toward Stable

Elimination of GMIP's based upon low occurrence of discrepancies and easy detection during surveillance.

(1999—eliminated 537 MAF inspections)

- b) Category D2—Progress Toward Stable/USA Transition

Determination that the GMIP's in this category would transfer to USA. (Transition never occurred.)

- Category E—High-Risk In-Family/Critical Last Opportunity

Determination that GMIP's in this category would not be eliminated.

This methodical approach reduced the GMIP's to a subset of the CIL inspections and tests and yielded 228 GMIP's. To offset this reduction, DCMA process monitoring was increased. This approach did not use indepth analysis to determine which GMIP's to retain but did use "best engineering judgment."

Between 2000 and 2003, the NASA GMIP Team performed safety risk reviews, which resulted in re-instatement of some GMIP's. Also, the Team added GMIP's to known problem areas. The current level of Government assurance points is approximately 586. This level of oversight still allows process monitoring.

Overall, the current program that evolved through this process is well defined and managed. The performance of GMIP's is an excellent starting point for providing assurance of the health of the processes and hardware processed at MAF but must be combined with other QA methods. There is no Government quality plan at the MAF to define a comprehensive QA Program. An overall quality plan and updated delegation, based on NASA's new environment and premise base, would further enhance their program.

External Tank assembly assurance requirements are defined in the MID's. The MID is maintained by DCMA and approved by the NASA senior S&MA representative at MAF. The GMIP IAT's assessments indicate that the MID commendably defines the assurance requirement, assurance type, and the associated manufacturing process for each GMIP. Recommended changes to the MID are submitted to the senior S&MA RMO representative for approval consideration. However, that which drives or constitutes a change to the MID is not clearly defined, nor is the process that governs GMIP modifications, additions, and deletions documented. Nondocumented processes and policies do not offer comprehensive program risk-mitigation approaches allowing for process and program improvement.

The following three tables include the IAT's facts, observations, and recommendations on MAF policy for the External Tank assembly.

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## MAF POLICY 1

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### **FACTS:**

1. Discussions with Government personnel and requests for documentation revealed GMIP determination was conducted in a logical fashion. The GMIP's were established using a clear methodical process; however, the process was not documented. Neither process stability nor trend data was considered in determining GMIP's.
2. Discussions and requests for documentation revealed that there is no documented policy or process to modify GMIP's. There is an undocumented process that seems to be working well.

### **OBSERVATION (WEAKNESS):**

- Although NASA defined guidelines and Team norms for the GMIP Reduction Team, NASA did not perform detailed analysis to support the reduction effort. Also, there is no documented programmatic policy, or criteria, governing the establishment or deletion of GMIP's.

### **RECOMMENDATION:**

- Develop and document a programmatic policy or criteria that governs the establishment or deletion of GMIP's.

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## MAF POLICY 2

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### **FACTS:**

1. A request for supporting documents revealed NASA S&MA does not have formal implementation plan(s) or an overarching quality plan that documents all QA functions at the MAF. The GMIP implementation portion was well documented in the MID. The letter of delegation is a well-written document but is limited in scope. The letter only defines GMIP requirements for oversight and some process monitoring.

2. There is documented direction from NASA to DCMA to discontinue data gathering for trend analysis. However, a subset of QAS's collected data by DCMA and used it to guide their process-monitoring efforts at the MAF.

**OBSERVATION (WEAKNESS):**

- There is no comprehensive QA plan for the MAF. NASA S&MA has not developed an inclusive plan that documents all the Government safety and QA functions at the MAF. The Letter of Delegation adequately defines the process monitoring and GMIP areas that DCMA performs, but no other documentation exists defining other Government QA activities.

**RECOMMENDATION:**

- Publish a comprehensive S&MA plan for resident office operations.

**OBSERVATION (WEAKNESS):**

- NASA MSFC does not have a fully integrated and structured QA program at MAF. The IAT witnessed GMIP's being used along with limited QAS-initiated trend analysis and loosely structured process monitoring and procedural compliance verification.

**RECOMMENDATIONS:**

- Develop and implement a well-defined, systemically deployed QA program that includes trending, audits, process mapping, process monitoring, process validation, mandatory assurances, training, material review, etc. This can proactively preclude errors, mitigate risk, and provide high degrees of rigor and focus.
- Investigate commercially available toolkits/benchmarking and best practices that can be readily adopted.

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## MAF POLICY 3

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**FACT:**

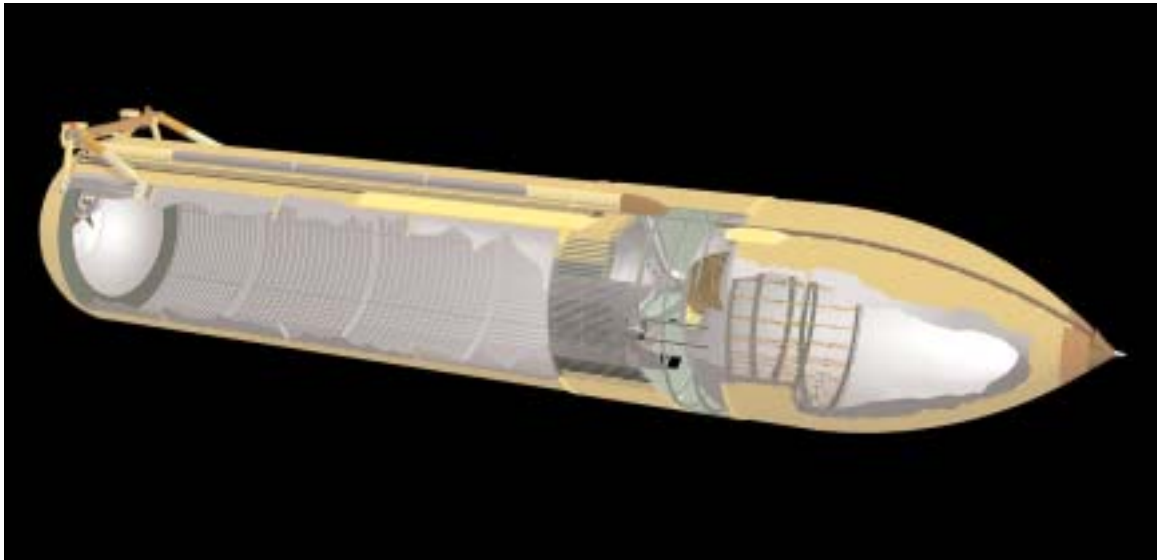
- Documentation requests revealed LM vendor trend charts reflecting supplier escape data. However, no requirement exists for LM to share vendor quality escape data with the Government. Discussions with Government personnel highlighted the necessity of receiving this information to adequately administer QA oversight of the contractor.

**OBSERVATION (WEAKNESS):**

- Although monthly trend data are presented to NASA management during the "Brown Book" review, there is no requirement for LM to share vendor quality escape data with the Government.

**RECOMMENDATION:**

- Add the contractual requirement to receive vendor quality escape data.



*Figure 6.*  
Perspective cutaway view of External Tank built at Michoud Operations.



*Figure 7.*  
External Tank rollout at Michoud Operations.

### 4.3.2 MAF ET Assembly GMIP Processes

The GMIP IAT reviewed the ET quality program with special attention given to the GMIP activity. At MAF, the GMIP activity is driven by the MID that lists all GMIP's to be performed. Unlike the QPRD used at KSC, the MID lists for each GMIP the inspection requirement, inspection type, a description of the activity to be performed by the QAS, and the associated manufacturing process plan/test procedure. The IAT concluded that the MID was an exceptional document that clearly spelled out all pertinent information for the assurances to be performed.

The contractor responsible for the build of the tank codes the GMIP's into the Manufacturing Planning Procedure (MPP), the work authorizing paperwork. The contractor receives instructions for adding GMIP's to the MPP via a NASA-authorized letter from DCMA. DCMA typically reviews the MPP to verify that changes were incorporated properly. The process of reviewing the MPP to assure intended GMIP incorporation is an essential and common sense practice; however, the Government does not have a documented closed-loop system to ensure that all GMIP's have been properly incorporated into the work authorizing documentation for each tank build.

DCMA QAS's perform the GMIP's and some process validation. Three types of GMIP assurances are performed: witness (watch), inspect (hands on), and verify (review results). The contractor, in this case Lockheed Martin, typically initiates the performance of a GMIP by notifying the DCMA QAS (phoning or paging) when a GMIP is required. If the operation meets all requirements, the QAS will stamp the appropriate GMIP step in the MPP. Nonconforming operations or hardware with GMIP's are documented by the QAS's on an LM Quality Control Worksheet (QCWS) to ensure that LM is immediately aware of the issue. The QAS also enters the nonconformance in the Defense Quality Assurance Reporting System (DQARS), the DCMA anomaly database. If the nonconformance is corrected in a timely manner, and to the satisfaction of the DCMA QAS, then the QAS will submit an "INFO ONLY" NASA Discrepancy Report (NDR) to the NASA senior S&MA representative at MAF. If the nonconformance is not resolved to the satisfaction of the DCMA QAS, the QAS will document the rejection of the LM response on an NDR and submit it to the NASA senior S&MA representative at MAF for further action. Significant QA system or flight hardware nonconformances are written in an NDR and submitted for action. This process appears to function in an effective and efficient manner. However, the DQARS database is antiquated, not easily queried, and is difficult to use for trending. Because DQARS has limited usefulness, most QAS's use the contractor database to pull data for history purposes and trending.

QAS's are typically assigned to one or more specific production area, which enables them to develop a deep understanding of the production processes and to perform insightful sampling and process validation. Assignment to a specific work area also instills a sense of ownership that was judged to be a strength of DCMA operations at MAF.

There is a process used for temporary GMIP application. There is also an informal process for adding GMIP's that seems to work very well; however, there is no periodic review of selected GMIP's nor the FMEA/CIL or those unique HA controls from which they are derived. Selected GMIP's should be reassessed for applicability based on documentation changes, process stability, and contractor's performance. This data assessment would require the collection and trending of data. While trending data are taken informally by the DCMA QAS's, there is no formal trending and data analysis process currently used by NASA or DCMA at the MAF. The NASA MAF resident S&MA Office does participate in the contractor's monthly trend data reviews.

Approximately 85 percent of the ET hardware is manufactured by subcontractors and suppliers and shipped to MAF for final build by LM. LM uses a "dock to stock" philosophy for receipt of material and hardware at MAF. The supplier retains all data packages. Successful execution of the dock-to-stock approach hinges

on the adequacy of the suppliers' quality control program and supplier oversight. NASA removed supplier Government oversight, GMIP process monitoring, and procedural compliance verifications. Supplier risk is not being adequately evaluated or monitored by NASA. The robustness of the contractor's Procurement Quality Assurance (PQA) Program is questionable in view of their dock-to-stock philosophy, which controls 75–80 first-tier suppliers and 70–80 second-tier suppliers with 16 PQA representatives. The IAT is aware of several notable supplier quality escapes that have had a detrimental effect on tank build operations. In the past, the contractor and suppliers quality system audits were conducted jointly between NASA, DCMA, and the contractor. There is no quality system audit function currently within the DCMA delegation, but NASA MAF S&MA plans to add it for FY04.

NASA S&MA RMO representatives are responsible for approval of required nonconformance dispositions and Material Review Board (MRB) activities at the MAF. Rework can be accomplished via a Rework Attachment Manufacturing Process Plan (RAM) without documenting the nonconformance in the nonconforming system; however, this practice impedes trending of these areas by QA for applicability to process monitoring. DCMA has no delegated MRB or trending functions. Currently, NASA is planning to add two NASA QE's to provide better coverage of MRB and the assembly facility floor activities.

The following eight tables represent the IAT's facts, observations, and recommendations on the External Tank processes.

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## MAF PROCESS 1

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### **FACTS:**

Through discussions and review of documentation, the IAT determined the following:

1. The MID defines all GMIP's and the method of assurance to be used for each GMIP.
2. There are no documented criteria or defined processes for adding or deleting assurance points. The only protocol that exists is an ad hoc process that works only because of experienced QAS's.
3. There is no periodic review of the adequacy of baseline GMIP's that fully takes into account feed-back on processes, governing documentation changes, GMIP implementation, and contractor's performance.
4. Some critical processes are not covered by adequate GMIP's (e.g., the hand spray Thermal Protective System processes).
5. Process control was not a factor in determining GMIP reductions.

### **OBSERVATIONS (STRENGTH):**

- The MID is an excellent document, clearly defining all pertinent information for the assurances to be performed by the Government.
- The GMIP reduction was performed following consistent, logical criteria.

### **OBSERVATIONS (WEAKNESS):**

- There are no documented criteria or processes for adding or deleting assurance points.
- Although the GMIP reduction was performed following consistent, logical criteria, the criteria allowed all GMIP's to be removed from some critical areas.

### **OBSERVATION (WEAKNESS):**

- GMIP's are inadequate in ensuring the integrity of some critical processes. GMIP's were completely deleted in the TPS hand spray areas with no objective evidence of process control. Reduction in GMIP's was made based solely on the GMIP Team's judgment. Based on discussions with DCMA, no data from other delegated activities were used to substantiate deletions.



**OBSERVATION (WEAKNESS):**

- There is no periodic review of the adequacy of baseline GMIP's that fully takes into account feedback on processes, governing documentation changes, GMIP implementation, and contractor's performance.

**RECOMMENDATION:**

- Establish a process to periodically assess the MID to assure accuracy and effectiveness of current requirements. Results from objective data analysis, process monitoring, and procedural compliance verification should be used to substantiate GMIP's. Also, all design, Interface Control Documents, process, and planning changes should be evaluated for impact to GMIP's. In view of the criticality of most TPS processes, the MID should be updated to include TPS activities. Consideration should be given to placing the MID under a formal configuration management (CM) control process that requires submission and approval of detailed change requests that fully document the rationale for the addition or deletion of each GMIP. The CM records should be maintained for the life of the project.

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## MAF PROCESS 2

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**FACT:**

- There is no systemically deployed process-monitoring and procedural compliance verification process that takes into account the criticality of processes and GMIP and process performance data.

**OBSERVATION (WEAKNESS):**

- The process-monitoring and procedural compliance verification has minimum structure and lacks a systemically deployed plan based on process data. Checklists approved by NASA govern these activities. Experienced individual QAS's with extensive corporate knowledge developed these checklists, but there was no methodical well-defined plan that included data indicators as well as corporate knowledge.

**RECOMMENDATION:**

NASA must:

- Develop and implement a structured process-monitoring and procedural compliance verification program that requires the use of data collection and analysis for trends across all MAF activities for monitoring the health of processes and products. Resultant data should be used to focus process-monitoring activities and GMIP's.

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## MAF PROCESS 3

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**FACT:**

- There is no formal documented process to verify that GMIP's have been properly incorporated into the contractor's build paperwork for each tank build. QAS's reported that GMIP's have been left out of the paperwork in the past.

**OBSERVATION (WEAKNESS):**

- NASA has no formal process to assure beforehand that GMIP's have been properly incorporated into the contractor's build paperwork. An informal undocumented process does seem to exist when GMIP's are added, deleted, or modified.



**RECOMMENDATION:**

- Establish a formal process to validate that all GMIP's have been adequately incorporated into the contractor's work authorizing documentation for each tank build.

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## MAF PROCESS 4

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**FACTS:**

1. There is no closed-loop accounting of GMIP's by the Government to validate that all GMIP's for a given tank build were conducted and properly closed out.
2. There is no system to track, review, and assess when a temporary GMIP is added to the manufacturing flow.

**OBSERVATION:**

- The contractor verifies all steps are completed prior to closing paperwork, but there is no closed-loop accounting of all GMIP's by the Government. There is no system to track, review, and assess when a temporary GMIP is added to the manufacturing flow.

**RECOMMENDATION:**

The Government should:

- Implement a tracking methodology to account for the performance of all GMIP's, including those that are temporary.

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## MAF PROCESS 5

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**FACTS:**

1. From document reviews discussions with Government personnel, the IAT learned that NASA removed supplier Government oversight, supplier process monitoring, and supplier procedural compliance verifications.
2. Eighty-five percent of ET manufacturing occurs at subtier suppliers.
3. The GMIP IAT has found a significant trend of supplier escapes.

**OBSERVATION (WEAKNESS):**

- NASA removed Government oversight, GMIP's, process-monitoring, and procedural compliance verification from supplier procurement operations. The supplier's risk to the program is not being evaluated or monitored by NASA (in view of the prime contractor's dock-to-stock philosophy).

**RECOMMENDATIONS:**

- Perform independent assessments of LM's control of suppliers consistently because of the large amount of supplier activity.
- Incorporate assessments of LM's performance of supplier audits, surveillance, and surveys into the NASA QA Program.
- Reinstitute subtier delegations due to the magnitude of supplier critical processes, operations, and escape trends.

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## MAF PROCESS 6

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**FACT:**

- The IAT found from document reviews and discussions with Government personnel that there are very few Government audits of contractor activity.

**OBSERVATION (WEAKNESS):**

- The Government is not performing sufficient quality system audits of contractor activity. Although NASA conducts an annual NASA Engineering and Quality Audit of Lockheed Martin, MAF, these audits are focused in scope.

**RECOMMENDATIONS:**

The S&MA Government representatives should:

- Include annual compliance audits as part of their oversight activities.
- Develop an audit function/process to perform QA system audits of ET operations.

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## MAF PROCESS 7

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**FACT:**

- All DCMA QAS's use the DQARS database to input GMIP and process-monitoring information.

**OBSERVATION:**

- The database, DQARS, is used by all QAS's to input GMIP and process-monitoring results monthly. These data allow tracking of specific location, date, time, and activity, and are reported to NASA on a monthly basis. However, the database is antiquated, is not easily queried, and is difficult to use for trending.

**RECOMMENDATION:**

- Adopt a better system for recording, trending, and reporting results of GMIP's and process-monitoring results. If practical, use a database common with the contractor that is accessible by all (as DQARS has limited usefulness, most QAS's use the contractor database).

**OBSERVATION (STRENGTH):**

- Materials that are received by LM are "fingerprinted" (comprehensive receipt inspection) for verification. This is an excellent practice for product quality verification.

**RECOMMENDATION:**

- Assess the practice of fingerprinting received materials for implementation across the Shuttle Program (e.g., as best practice of the Process Control Focus Group).

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## MAF PROCESS 8

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### **FACTS:**

1. Data documented from fingerprinting that are out of family (OOF) are not shared with NASA; however, nonconforming data are shared with NASA.
2. LM engineers disposition all OOF and nonconformance data.

### **OBSERVATION (WEAKNESS):**

- Fingerprinting data determined to be OOF but within specification are assessed by the LM Material Data Action Team (MDAT) and dispositioned for usage. These OOF data could indicate a significant process deviation. The data are not shared with NASA, nor does NASA have insight into the decisions to use the OOF material.

### **RECOMMENDATION:**

- All OOF data should be provided to and reviewed by NASA.

### **OBSERVATION (WEAKNESS):**

- Not all LM process initiatives to improve workflow or efficiencies are coordinated with Government S&MA. Coordination with the Government is necessary and recommended to assess the need for additional quality oversight and to implement it if needed.

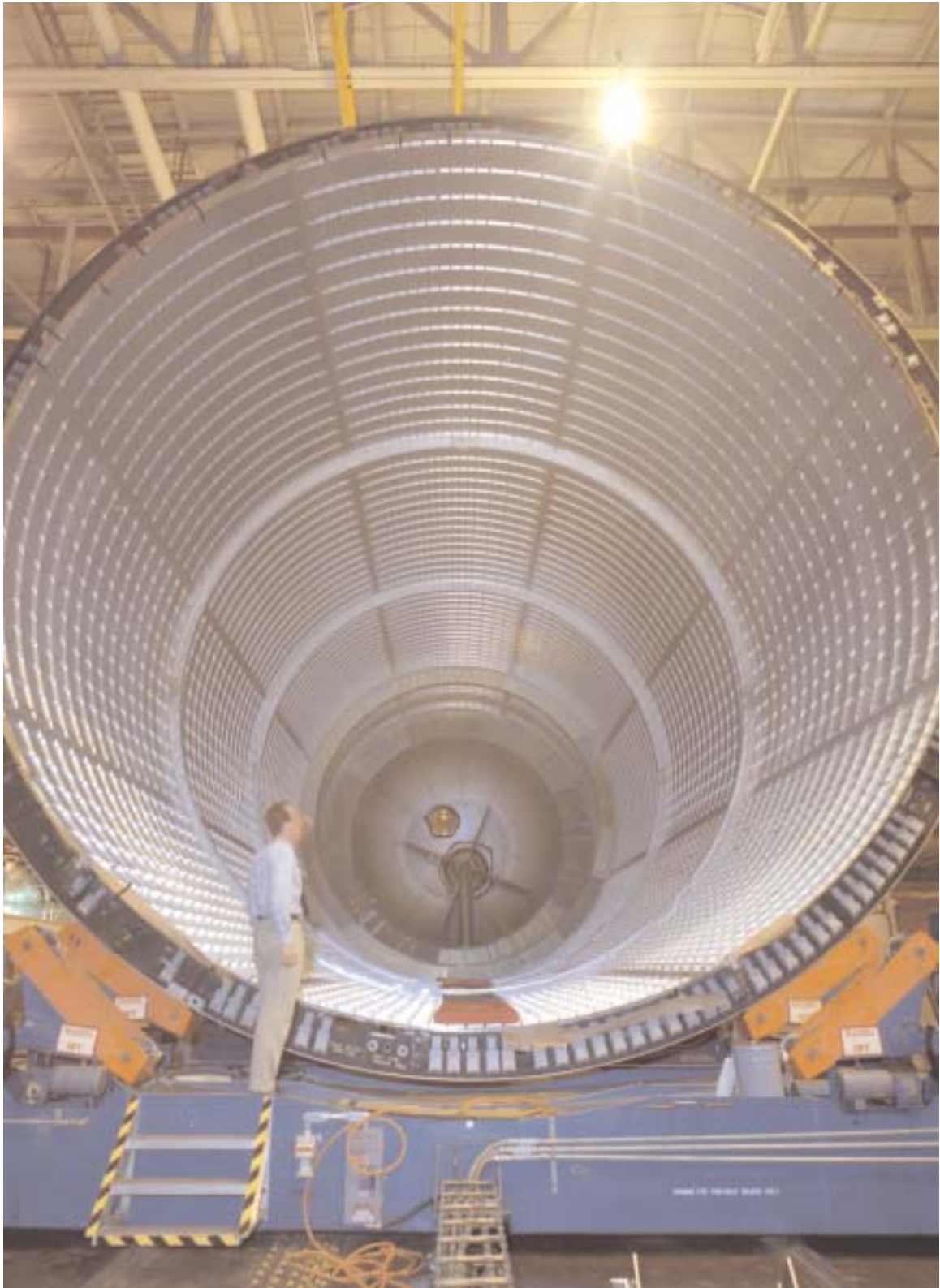


Figure 8.  
External Tank—looking into the liquid hydrogen end.



*Figure 9.*  
External Tank leaving final assembly and being taken to final test and checkout.

### 4.3.3 MAF ET Assembly GMIP Workforce

Although the IAT did not note any evidence that required delegated activities were being missed, the current MAF workforce staffing level is minimal at best. Once the Shuttle Program decides on the scope of a full quality and mission assurance program, the Team will need to be expanded to meet those requirements. The workforce at MAF is composed of experienced people with widely varied, but complementary, skills and abilities. The current staff of NASA RMO engineers and DCMA QAS's is an excellent group to mentor any new employees who are hired to meet the new requirements.

Growth beyond a robust QA Program should be examined because oversight of return-to-flight modifications may overwhelm the current workforce. Although NASA is taking action to fill current RMO vacancies, there is also a high level of near-term retirement eligible personnel that requires workforce and succession planning. Additional action should be taken to account for attrition and supplier oversight, and to determine the correct manpower to meet a comprehensive program.

DCMA has extensive documented training and certification requirements. All employees have an individual development plan that includes required training to support NASA delegations in addition to any certifications required to perform their jobs. To enhance job performance, additional training of DCMA technicians in the contractor TPS operations should be considered. The training needs to be fully documented and include proper certification to support the credibility of the workforce to the program and contractors. Further familiarization/training should be given to all QAS's explaining where they fit into their assigned team and how their team contributes to the overall Shuttle quality program and flight safety.

Lessons learned are buried in rework paper and the tacit knowledge of the current workforce on the floor. QAS's held that contractor technicians and inspectors fear that discovered and reported errors would lead directly to disciplinary action. There was an admitted culture to correct errors whenever possible without documentation, in particular, when an inspector stops an error from occurring during an action in process. A culture change is required to give incentive to the contractor to document and report all types of errors and encourage communicating the lessons learned to all program elements. Employees should be disciplined for errors only after they have been given every opportunity to successfully perform their job.

The following four tables are the IAT's facts, observations, and recommendations on the MAF workforce.

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## MAF WORKFORCE 1

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### FACTS:

1. Discussions with QAS's and NASA RMO representatives revealed the type and scope of work performed was a function of GMIP demands being met with any spare workforce being applied in an ad hoc fashion to process monitoring. With no comprehensive program, process monitoring was guided by a checklist and current contractor activity at the plant. The workforce determined the activity performed instead of the workforce level being determined by a comprehensive program.
2. Discussions with NASA RMO representatives revealed that NASA's plan to use current manpower to cover the increase in oversight activity was caused by RTF ET modifications. This surge of activity is being met by suspending all oversight activity except for GMIP's. The workforce level continues to drive the oversight activity.
3. During discussions, Government personnel consistently stated that the workforce is spread too thin.
4. Management planned to bring other DCMA personnel in temporarily from local sites if the GMIP demands exceeded their workforce capability.



5. The NASA/MSFC Resident Office has had two vacancies for S&MA engineers for over 12 months. Discussions with QAS's showed a strong desire for a larger NASA presence in the MAF to support and develop their oversight activity.
6. Discussions with the DCMA workforce at the MAF revealed that many MAF QAS's are retirement eligible or considering retirement in the near future.

**OBSERVATION (STRENGTH):**

- The way DCMA assigns QAS's to specific areas or work centers enables the QAS's to develop a high degree of knowledge about processes, what to look for, and what could go wrong. This practice appears to instill a high sense of ownership. The DCMA workforce seems highly experienced and well qualified to perform its current task.

**OBSERVATION (WEAKNESS):**

- NASA and DCMA quality workforce is minimal and inadequate to perform the level of oversight, auditing, process monitoring, and trend analysis that a project this size and criticality warrants.

**OBSERVATION (WEAKNESS):**

- Oversight of RTF modifications for the ET has a strong possibility of overwhelming the existing Government quality resources. To perform oversight with current staffing levels, current process-monitoring and procedural compliance verification activities may be compromised.

**OBSERVATION (WEAKNESS):**

- The NASA/MSFC Resident Office has been unsuccessful in filling two S&MA engineering vacancies. Positions have been vacant for over 12 months.

**OBSERVATION (WEAKNESS):**

- DCMA succession planning does not appear to account for the high number of retirement possibilities and the ability to attract and retain skill levels with commensurate grade to shape future workforce.

**RECOMMENDATION:**

- Perform an assessment to determine the Full Time Equivalents (FTE's) required to accomplish the mission and fill the vacancies, and, if necessary, acquire resources to perform the mission. Manpower and succession planning should accommodate upcoming retirements and capability to attract and retain a robust quality workforce. The solution needs to account for ET modification oversight without compromising a complete assurance program.

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## MAF WORKFORCE 2

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**FACTS:**

1. The QAS's report being told by NASA management that trending is not part of their oversight duties.
2. There is informal training in trending and analysis but no formal training, and very few tools are available.
3. The DQARS database is outdated and ill suited for trending and analysis.

**OBSERVATION (WEAKNESS):**

- Most of the ET Government workforce is marginally equipped to conduct these activities; although some of the QAS's are proficient in data gathering, trending analysis, and process validation.

**RECOMMENDATION:**

- Obtain training for the ET Government workforce to equip them for data gathering, analysis, and process validation to enhance their quality core competency.

**OBSERVATION (WEAKNESS):**

- QAS's attitudes and support of MAF oversight programs were clearly related to their participation in the process. QAS's on the team deciding what a GMIP should be were more supportive of the current process and policies than other personnel. QAS's outside the GMIP determination team did not receive training or briefings to help them understand and accept the sweeping changes and paradigm shifts that occurred over the years. The direct relationship between their participation, education, and program support shows the value of a comprehensive program at all levels of activity.

**RECOMMENDATION:**

- Explain to the ET Government QA workforce the reason for the sweeping changes and how to accept and fully support any QA paradigm shift, like oversight to insight. This must occur at all levels.

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## MAF WORKFORCE 3

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**FACT:**

- Based on discussions with Government workers, there are concerns about reporting contractor errors, including "close calls" and "caught before made" errors. Some thought that reporting these errors could result in disciplinary action for the contractor.

**OBSERVATIONS (WEAKNESS):**

- The workforce needs to be encouraged to document and report all types of errors, including those made and corrected in real time.
- The culture must focus on learning from mistakes, not on punishing workers for making mistakes.

**RECOMMENDATION:**

- The MAF needs to develop a culture where workers are encouraged to report mistakes, knowing that the reports will be used to reduce the root causes of the mistakes and not to punish the worker making the mistake. Successful examples NASA could use to benchmark such a culture change and error-tracking and correction system are the Patient Safety Program initiated by the Veterans Administration in its hospitals and the Aviation Safety Action Program (ASAP) initiated by the FAA with American Airlines and now used by several commercial airline companies.

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## MAF WORKFORCE 4

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**FACT:**

- DMCA QAS's did not receive necessary training on all ET-unique critical processes (i.e., TPS applications).

**OBSERVATION:**

- All DCMA QAS's have individual development plans that include required training to support NASA delegations in addition to any national certifications required to perform their jobs. However, QAS's have not received any training or certifications on TPS processing and application. A large percentage of manufacturing operations on ET at MAF are TPS.

**RECOMMENDATION:**

- Consider additional training of DCMA technicians in the contractor TPS operations. Thorough training of all personnel for their areas of responsibility is essential and must be incorporated into any QA Program.



*Figure 10.*  
Thermal Protection System hand spray demonstration.

## 5. Conclusions

The Independent Assessment Team assessed the NASA Quality Assurance Programs for the Orbiter and External Tank Space Shuttle Program elements, with a focus on Government Mandatory Inspection Points, as it was impossible to properly assess the effectiveness of the Government Mandatory Inspection Points without understanding the context in which they were applied. The Team found that the NASA Quality Assurance Programs in place today for the Orbiter and External Tank Space Shuttle Program elements are relatively good based upon the ground rules that were in place when they were formulated. However, the ground rules have changed, and NASA should reassess their quality assurance requirements based on the new premise base and establish a NASA quality assurance effort that fulfills those requirements. The workforce should be adjusted and trained accordingly.

The new premise base is as follows.

- The Space Shuttle is a developmental vehicle that is also an aging vehicle.
- The Space Shuttle must function for at least another decade.
- The Space Shuttle Program is a relatively high-risk program.
- The NASA Safety and Mission Assurance Quality Assurance Program must help to ensure both safe hardware and an effective contractor quality program.



*Figure 11.*

Workers add to the Astronaut Memorial Mirror the names of the Columbia crew who died in the STS-107 accident.



*Figure 12.*  
Launch of STS-107.



# APPENDIX A

## References

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# APPENDIX B

## List of Acronyms

ASAP . . . . .	Aviation Safety Action Program (FAA and American Airlines)
ATP . . . . .	Acceptance Test Procedure
CAIB . . . . .	Columbia Accident Investigation Board
CIL . . . . .	Critical Items List
CM . . . . .	Configuration Management
COFR . . . . .	Certificate of Flight Readiness
CVAS . . . . .	Configuration Verification Accounting System
DCMA . . . . .	Defense Contract Management Agency
DDMS . . . . .	Department of Defense Manned Spaceflight
DQARS . . . . .	Defense Quality Assurance Reporting System
DRD . . . . .	Data Requirements Description
FAR . . . . .	Federal Acquisition Regulations
FMEA . . . . .	Failure Mode and Effects Analysis
GMIP . . . . .	Government Mandatory Inspection Points
GSE . . . . .	Ground Support Equipment
HST . . . . .	Hubble Space Telescope
IAT . . . . .	Independent Assessment Team
IPR . . . . .	Interim Problem Report
JSC . . . . .	Johnson Space Center, Houston, TX
KDP . . . . .	Kennedy Documented Process
KSC . . . . .	Kennedy Space Center, FL
LARC . . . . .	Langley Research Center, Hampton, VA
LM . . . . .	Lockheed Martin
MAF . . . . .	Michoud Assembly Facility, New Orleans, LA

MDAT. . . . . Material Data Action Team

MID . . . . . Mandatory Inspection Document

MIP. . . . . Mandatory Inspection Point

MRB. . . . . Material Review Board

MSFC. . . . . Marshall Space Flight Center, Huntsville, AL

NDE . . . . . Nondestructive Evaluation

NPD . . . . . NASA Policy Directive

NPG . . . . . NASA Procedures and Guidelines

NSLD . . . . . NASA Shuttle Logistics Depot

NSTS . . . . . National Space Transportation System

OMM . . . . . Orbital Major Modifications

OMRSD . . . . . Operations and Maintenance Requirements and Specifications Document

OOF . . . . . Out of Family

OPF . . . . . Orbiter Processing Facility

OSMA . . . . . Office of Safety and Mission Assurance

PA. . . . . Process Analyst

PQA . . . . . Procurement Quality Assurance

PRACA. . . . . Problem Reporting and Corrective Action

QAS . . . . . Quality Assurance Specialist

QE . . . . . Quality Engineer

QPRD. . . . . Quality Planning Requirements Document

RCC . . . . . Reinforced Carbon-Carbon

RTF. . . . . Return to Flight

SE. . . . . Systems Engineers

SFOC . . . . . Space Flight Operations Contract

SHIA . . . . . Safety, Health, and Independent Assessment

SIP ..... Surveillance Inspection Point

SLEP ..... Space Shuttle Service Life Extension Program

S&MA ..... Safety and Mission Assurance

SMART ..... S&MA Reporting Tool

SR&QA ..... Safety, Reliability, and Quality Assurance

SSME ..... Space Shuttle Main Engine

SSP ..... Space Shuttle Program

TPS ..... Thermal Protection System

VAB ..... Vehicle Assembly Building

WAD ..... Work Authorization Document

ZBR ..... Zero-Base Review

# APPENDIX C

## Alphabetical Listing of Terms and Definitions

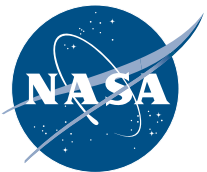
Term	Definition	Source
Acceptance	The act of an authorized agent of the procuring organization by which the procuring organization assents to ownership of existing and identified contract items or approves specific services render as partial or complete performance of a contract.	1D-2
Assessment		
Audit	Review or audit process, using predetermined methods, that evaluates hardware, software, procedures, technical and programmatic documents, and the adequacy of their implementation.	NPG 8715.3
Corrective Action	Systematic, independent, and documented process for obtaining evidence and evaluating it objectively to determine compliance with hardware or software requirements, specifications, baselines, safety standards, procedures, instructions, codes, and contractual and licensing requirements.	NPG 8715 Draft 2; ZQMRf
Cost of Quality	<p>Action taken to preclude continuation of a discrepancy, problem, or recurrence of a mishap.</p> <p>The costs associated with providing quality products or services. There are four categories of costs:</p> <ul style="list-style-type: none"> <li>- internal failure costs (costs associated with defects found before the customer receives the product or service, including scrap, rework, retest, downtime, yield losses, and disposition),</li> <li>- external failure costs (costs associated with defects found after the customer receives the product or service, including complaint adjustment, returned material, warranty charges, and allowances),</li> <li>- appraisal costs (costs incurred to determine the degree of conformance to quality requirements, including incoming material inspection, inspection and test, maintaining accuracy of test equipment, materials and services consumed, and evaluation of stocks), and</li> <li>- prevention costs (costs incurred to keep failure and appraisal costs to a minimum, including</li> </ul>	

Cost of Poor Quality	<p>quality planning, new products review, training, process control, quality data acquisition and analysis, quality reporting, and improvement projects).</p> <p>The costs incurred due to defective products and services include:</p> <ul style="list-style-type: none"> <li>- internal failure costs (costs associated with defects found before the customer receives the product or service, including scrap, rework, retest, downtime, yield losses and disposition), and</li> <li>- external failure costs (costs associated with defects found after the customer receives the product or service, including complaint adjustment, returned material, warranty charges, and allowances).</li> </ul>	
Deviation	Specific written authorization, granted prior to the manufacture of an item, to depart from a particular performance or design requirement of a specification, drawing, or other document for a specific number of units or a specified period of time. A deviation differs from an engineering change in that an approved engineering change requires corresponding revision of the documentation defining the affected item, whereas a deviation does not contemplate revision of the applicable specification or drawing.	ZQQ
Discrepancy	A condition of any hardware or software in which one or more characteristics do not conform to the specified requirements (see Nonconformance).	NPG 8621.1
Escape—Quality	Any problem found after it should have been detected during normal processing. Escapes include problems found during surveillance sampling, inspection (including random), or audit after closeout or test. Also, if an assessment determines that the problem would not have been caught during closeout or test, the problem will be considered a quality escape.	
Functional Configuration Audit (FCA)	Verifies that the hardware and software configuration items meet the functional requirements of the specification and establishes the functional configuration baseline; integration test results and documentation are part of this audit.	ZQSA
Independent Assessment	A customer-driven, thorough, and expeditious, non-advocate evaluation of program/project activities and the ability of the program/project to obtain mission	NPG 7120.5A; ZQAP



	success. IAs may include selected SRM&QA areas, program-/project-specific technical areas, management issues, or all of the above.	
Inherently Government Function	As a matter of policy, a function that is so intimately related to the public interest as to mandate performance by Government employees. This definition is a policy determination, not a legal determination. An inherently Government function includes activities that require either the exercise of discretion in applying Government authority or the making of value judgments in making decisions for the Government. Governmental functions normally fall into two categories: the act of governing (i.e., the discretionary exercise of Government authority) and monetary transactions and entitlements (FAR 7.501).	NPG 8735.2
Insight	Surveillance mode requiring the monitoring of customer-identified metrics and contracted milestones. Insight is a continuum that can range from low intensity, such as reviewing quarterly reports, to high intensity, such as performing surveys and reviews.	NPG 8715.1
Inspection	Examination and testing of supplies or services (including, when appropriate, raw materials, components, and intermediate assemblies) to determine whether they conform to contract requirements (FAR 46.101). For the ISO 9000 series of international quality standards, ISO 8402, Quality Management and QA—Vocabulary, defines inspection as “activity such as measuring, examining, testing, or gauging one or more characteristics of an entity and comparing the results with specified requirements to establish whether conformity is achieved for each characteristic.”	ZQSA
Nonconformance	A condition of any article, material, or service in which one or more characteristics do not conform requirements specified in the contract, drawings, specifications, or other approved product description. Includes failures, discrepancies, defects, anomalies, and malfunctions.	ZQCM
Nondestructive Evaluation (NDE)	Test and inspection methods (used to determine the integrity of equipment) that do not involve destruction of the test object. Examples are ultrasonic, magnetic particle, eddy current, x ray, dye penetrant, etc.	NPG 8735.2
Oversight	Surveillance mode that is in line with the supplier's processes. The customer retains and exercises the right to concur or nonconcur with the supplier's	

	decisions. Nonconcurrency must be resolved before the supplier can proceed. Oversight is a continuum that can range from low intensity, such as customer concurrence in reviews (e.g., PDR, CDR), to high intensity oversight, in which the customer has day-to-day involvement in the supplier's decisionmaking process (e.g., hardware inspections).	
Process Control	Maintaining, without deviation, established processes and procedures	S&MA Strategic Plan
Quality	<p>Quality is the "totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs." A quality system should address the four facets of quality:</p> <ul style="list-style-type: none"> <li>• quality due to definition of needs,</li> <li>• quality due to manufacturing,</li> <li>• quality due to product design,</li> <li>• quality due to conformance, and</li> <li>• quality due to product support throughout its lifetime.</li> </ul>	NPG 7120.5A
Quality Assurance (QA)	Functions, including inspection, performed to determine whether a contractor has fulfilled the contract obligations pertaining to quality and quantity (see FAR 46). As defined in ISO 8402, QA means, "all the planned and systematic activities implemented within the quality system, and demonstrated as needed, to provide adequate confidence that an entity will fulfill requirements for quality."	NASA STD 2100-91
Government Contract Quality Assurance (GCQA)	The various functions, including verification, performed by or for the Government to determine whether a contractor has fulfilled the contract obligations pertaining to the quality and quantity.	
Surveillance Inspection Point (SIP)	An SIP is a temporary GMIP that may be stamped into the work documentation by a KSC QAS.	
Waiver	A written authorization, granted after the fact, for use or acceptance of an article that does not meet the specified requirements.	ZQMI



National Aeronautics and  
Space Administration